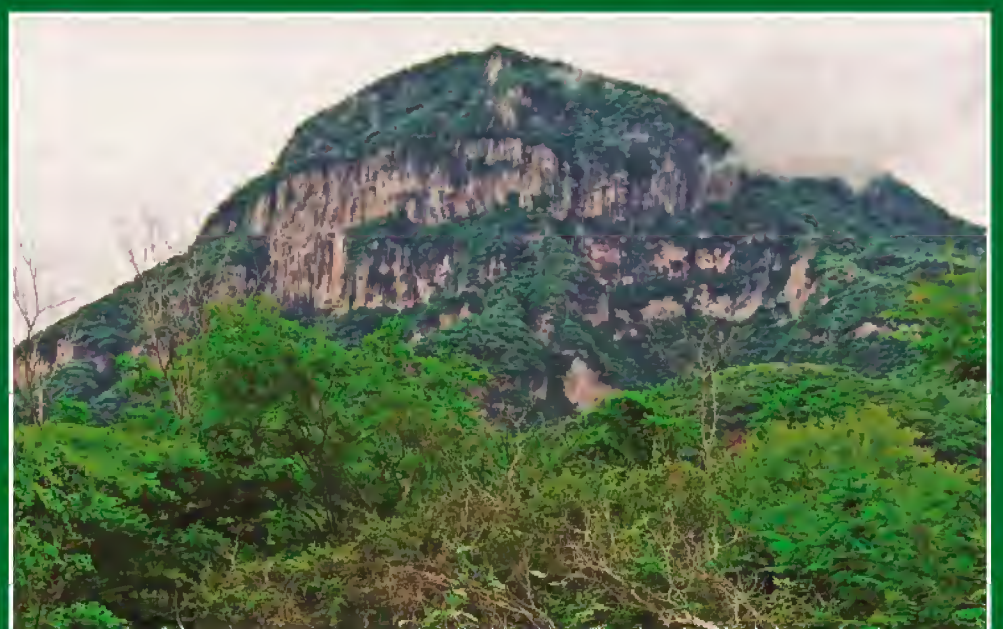


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Cover:

Upper left: *Bolitoglossa franklini*. Photo by Sean Rovito.

Upper right: *Diaglena spatulata*. Photo by Oscar Medina Aguilar.

Center left: *Agkistrodon bilineatus*. Photo by Chris Mattison.

Center right: *Trachemys gaigeae*. Photo by Vicente Mata-Silva.

Lower left: *Heloderma horridum*. Photo by Tim Burkhardt.

Lower right: Cerro Mariana, Balsas-Tepalcatepec Depression, ca. 12 km NW of Caracuaro, Michoacán.
Photo by Javier Alvarado-Díaz.

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PREFACE

AMPHIBIAN & REPTILE CONSERVATION

SPECIAL MEXICO ISSUE

Citation: Wilson LD. 2013. Preface (*Amphibian & Reptile Conservation* Special Mexico Issue). *Amphibian & Reptile Conservation* 7(1): i–ii.

The allure of Mexico first beckoned me in 1957, but only from across the border, as along with my parents and sister I was visiting family members in Mission, Texas. Mission is a bit west of McAllen, just north of the international border, with Reynosa located on the southern bank of the Río Bravo directly across from McAllen. We went to Reynosa just to say we had been in Mexico.

My first herpetological trip to Mexico occurred in 1966, when Ernest A. Liner kindly took me on one of his many journeys. We traveled as far south as Chiapas, and saw much of the country and plenty of amphibians and reptiles.

In the ensuing years, I traveled south of the border on several occasions, and ultimately visited all but one of Mexico's 31 states. Among several others, I took one of those trips with Louis Porras, the senior author of the paper on cantils in this issue. I made another extensive trip with my father, Ward Wendell Wilson, and visited many of the ancient ruins for which the country is well known.

During my career I have always been interested in Mexico, although in recent years I spent much of my time in Central America. Nevertheless, I was delighted at the opportunity to work on the book *Conservation of Mesoamerican Amphibians and Reptiles* (2010), which dealt with all of Mexico and Central America. This massive undertaking presented me with the chance to work closely with two long-time friends, Jerry Johnson, one of my co-editors, and Louis Porras, the proprietor of Eagle Mountain Publishing, LC, and both are involved in this Special Mexico Issue.

The herpetofauna of Mexico is impressive from a number of perspectives. At 1,227 species, it is almost twice the size of that of its northern neighbor (presently, the United States is known to contain 628 native species, according to the Center for North American Herpetology [naherpetology.org]; data accessed 17 March 2013); Mexico, however, is only about one-fifth the size of the United States. Mexico's herpetofauna also is larger than that of the seven Central American nations combined (1,024 native species, according to Wilson and Johnson [2010], and my updating since), although the disparity between Mexico and its southern neighbors is much smaller. Notably, Central America's land area is slightly over one-fourth that of Mexico.

The level of endemism in Mexico also is spectacular. In this Special Mexico Issue, Wilson, Mata-Silva, and Johnson report that 482 species of reptiles (excluding the marine species) of a total of 849 (56.8%) are Mexican endemics; Wilson, Johnson, and Mata-Silva indicate that 253 species of amphibians of a total of 378 (66.9%) are not found outside of Mexico. The combined figure is 736 endemics out of 1,227 species (60.0%), a percentage substantially higher than that for Central America. In Central America, 367 endemic species have been recorded to date (Wilson and Johnson [2010], and my updating since), which equates to 35.8%. According to the accounting at the Center for North American Herpetology website (www.cnah.org), however, compared to the figures for Mexico (see the two Wilson et al. papers indicated below), Canada (www.carcnet.ca) and the West Indies (Powell and Henderson 2012), of the 628 species listed, 335 are endemic to the United States, for which the resulting percentage (53.3%) is much closer to that of Mexico than for Central America. Because the United States is about five times the size of Mexico, when one compares the degree of endemism in these two countries with their respective land areas (area/number of endemics), the resulting figures (areas from the CIA World Factbook; www.cia.gov) are as follows: Mexico ($1,943,945 \text{ km}^2/736 = 2,641$); and the United States ($9,161,966 \text{ km}^2/335 = 25,808$). Thus, the area/endemism ratio for the United States is almost 10 times that of Mexico, indicating that endemism in Mexico is that much greater than that of its neighbor to the north. The comparable figure for Central America is $507,966 \text{ km}^2/367 = 1,384$, which is even lower than that for Mexico, and this region already is regarded as a major source of herpetofaunal diversity (Wilson et al. 2010).

The Mexican herpetofauna also is of immense importance and interest from a conservation standpoint. In both of the Wilson et al. papers indicated below, the authors applied the Environmental Vulnerability Score (EVS) measure to Mexico's herpetofauna and found that 222 of 378 amphibian species (58.7%) and 470 of 841 reptile species (55.9%) were assigned an EVS that falls into the high vulnerability category. In total, 692 species (56.8%) fall into the highest category of susceptibility to environmental deterioration. The relatively small portion

of humanity that recognizes the value and critical necessity of biodiversity is fighting an uphill battle to salvage as much biodiversity as possible before it disappears into extinction (Wilson 2006). Given the rate of human population growth and the commensurate rate of loss of natural habitats, populations of these unique components of the Mexican patrimony likely will decline steadily, as is happening over the remainder of the planet (Raven et al. 2011).

One of the most important imperatives we face, therefore, is to take appropriate steps to conserve the Mexican herpetofauna. Toward this end, five papers collectively written by 10 contributors are expected to appear in this Special Mexico Issue of *Amphibian & Reptile Conservation*. These papers are as follows:

A conservation reassessment of the reptiles of Mexico based on the EVS measure by Larry David Wilson, Vicente Mata-Silva, and Jerry D. Johnson.

*A taxonomic reevaluation and conservation assessment of the common cantil, *Agkistrodon bilineatus* (Squamata: Viperidae): a race against time* by Louis W. Porras, Larry David Wilson, Gordon W. Schuett, and Randall S. Reiserer.

Patterns of physiographic distribution and conservation status of the herpetofauna of Michoacán, Mexico by Javier Alvarado-Díaz, Ileri Suazo-Ortuño, Larry David Wilson, and Oscar Medina-Aguilar.

*Taxonomic reevaluation and conservation of beaded lizards, *Heloderma horridum* (Squamata: Helodermatidae)* by Randall S. Reiserer, Gordon W. Schuett, and Daniel D. Beck.

A conservation reassessment of the amphibians of Mexico based on the EVS measure by Larry David Wilson, Jerry D. Johnson, and Vicente Mata-Silva.

All of these papers deal with issues of herpetofaunal conservation, and range in coverage from the entire country of Mexico, through a single Mexican state, to what have been regarded as single species. Each study provides a set of recommendations.

These five papers are gathered under this Preface and an issue cover. The concept behind the cover is to draw the papers into a coherent whole that reinforces the mission of the journal, which is to “support the sustainable management of amphibian and reptile biodiversity.” Thus, the photograph of Cerro Mariana, located in the Balsas-Tepalcatepec Depression between Huetamo and Morelia, in Michoacán, is intended to illustrate dry forest, the type of vegetation most heavily damaged in Mesoamerica (Janzen 1988), one of the major features of the state’s environment and in which a significant portion of the herpetofauna is found. This type of environment is

inhabited by two of the reptiles featured in this issue, the common cantil (*Agkistrodon bilineatus*) and the beaded lizard (*Heloderma horridum*), as well as the shovel-headed treefrog (*Diaglena spatulata*); all three of these species are relatively broadly distributed in subhumid environments along the Pacific coastal region of Mexico, as well as in the extensive valley of the Balsas and Tepalcatepec rivers, of which the western portion lies in the state of Michoacán.

Finally, our aim is to examine the conservation status of the amphibians and reptiles of Mexico, in general, and to focus more closely on a state herpetofauna (of Michoacán) and on two prominent and threatened Mexican flagship species, the common cantil and the beaded lizard. Thus, we hope to contribute to the ongoing effort to provide for a sustainable future for the world’s amphibians (Stuart et al. 2010) and reptiles (Böhm et al. 2013).

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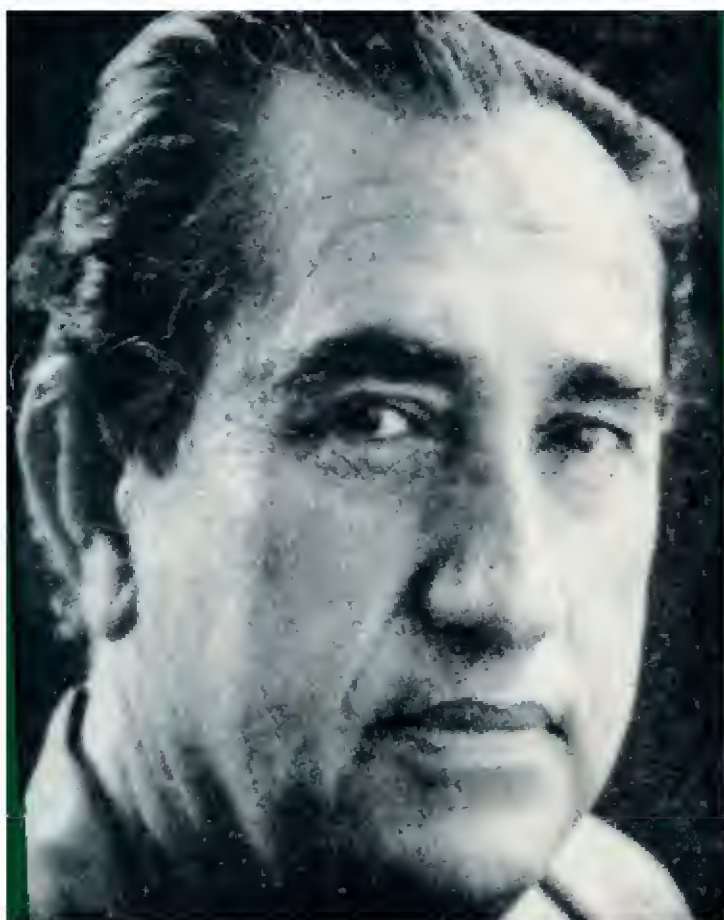
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Larry David Wilson
2 May 2013

DEDICATIONS

Citation: Johnson JD, Porras LW, Schuett GW, Mata-Silva V, Wilson LD. 2013. Dedications (*Amphibian & Reptile Conservation* Special Mexico Issue). *Amphibian & Reptile Conservation* 7(1): iii–vi.

With the publication of this Special Mexico Issue (SMI), the contributing authors were provided with an opportunity to dedicate it to herpetologists who have played a significant role in their lives, as well as the lives of other herpetologists past and present. Each of the 10 contributors was asked to identify the person who was most influential in their respective careers, especially with respect to what each of them has contributed to SMI. The dedicatees are:



Miguel Álvarez del Toro.

Miguel Álvarez del Toro (August 23, 1917–August 2, 1996) was born in the city of Colima, Colima, México, according to an obituary in *Herpetological Review* by Oscar Flores-Villela and Wendy Hodges in 1999. He moved to Mexico City in 1932, where he attended and later graduated from high school. Although his formal education was limited, his reputation as an avid naturalist spread rapidly and at the age of 21, while still in Mexico City, he began a long career devoted to a multitude of zoological and conservation related disciplines. He moved to Chiapas in 1942, and after a short stint as keeper and curator became the Director of what then was known as the Instituto de Historia Natural located near downtown Tuxtla Gutiérrez. His reputation grew exponentially because of his tireless work at the Zoological Park and Natural History Museum, his publication record, including books and papers on numerous vertebrate and invertebrate groups, and his solemn activism on conservation issues. One of his greatest legacies was convincing several generations of politicians in Chiapas to help develop a system of natural protected

areas, and also to expand the Zoological Park and move it to “El Zapotal,” a relatively pristine site on the southern edge of the city. That new and remarkable facility was named “Zoológico Regional Miguel Álvarez del Toro, or ZOOMAT as it is popularly called today. Because of his lifetime efforts, “Don Miguel,” as he was called respectfully, was justly awarded honorary doctoral degrees from the Universidad de Chapingo, in 1992, and from the Universidad Autónoma de Chiapas, in 1993. Over his long career he received a plethora of other awards, and also was involved in numerous conservation projects in conjunction with various local, state, national, and international organizations.

Jerry D. Johnson, an avid “herper” since grade school and recently discharged from the Marine Corps after a stint in Viet Nam, enrolled in the 1971 wintermester course at Fort Hays State University (Kansas), and accompanied Dr. Charles A. Ely to Chiapas on a migratory bird study. Dr. Ely, after recognizing Johnson’s eagerness to search for amphibians and reptiles through all sorts of tropical and highland environments, included him on many return trips during the next several years. On that initial 1971 trip, Johnson briefly met Don Miguel at the old Zoological Park. In 1974, Dr. Ely arranged for he and Johnson to pitch tents in Don Miguel’s back yard, located near the Zoo. This initiated an opportunity to mingle with all sorts of interesting people, including the Álvarez del Toro family, their friends, and a continuous flow of traveling naturalists who were visiting the Zoo. During those times Johnson realized just how influential Don Miguel’s scientific and conservation work had become, in Chiapas and elsewhere. On a typical day, Don Miguel often would walk among the Zoological Park’s animal enclosures, and during those walks Jerry came to know him while discussing the status of herpetology in Chiapas, how conservation efforts were in dire straits, and pondering his doubts about the possibility that anything resembling a natural Chiapas would persist into the future. In 1985, Don Miguel published a book entitled *¡Así Era Chiapas!* that described how Chiapas had changed in the 40 years since he had arrived in the state. Even today, Johnson often thinks about how habitat destruction had altered the Chiapan environment since he began investigations there in 1971, as a college sophomore. He now realizes that his life and professional experiences have passed rather quickly, but sadly, environmental decay is accelerating at an even greater pace. Johnson now concentrates much of his professional efforts on conservation issues, hoping that humankind can avoid total environmental devastation. Jerry also is reasonably sure that Don Miguel really didn’t expect preservation efforts to be very successful,

but he didn't give up his dream of a more conservation-oriented populace by continually teaching people why preserving natural habitats is important to their own well-being, which probably is the only way conservation will ever succeed. With great pleasure, Johnson dedicates his contributions to this special Mexico edition of *Amphibian and Reptile Conservation* to Miguel Álvarez del Toro, who in his opinion was the leading advocate and pioneer of biodiversity conservation in 20th century Mexico.



Roger Conant in his early 20s.

Roger Conant (May 6, 1909–December 19, 2003) was born in Mamaroneck, New York, USA. As a child he developed a passion for reptiles, especially snakes, and at the age of 19 became the Curator of Reptiles at the Toledo Zoo. After assembling a sizeable collection of reptiles for public display, he was promoted to General Curator. Because of the close proximity of Toledo to Ann Arbor, he occasionally would visit herpetologists at the University of Michigan and became close friends with a then-graduate student, Howard K. Gloyd. Eventually, Roger left Toledo to become the Curator of Herpetology at the Philadelphia Zoo, and in time became the zoo's Director. Throughout his 38-year career at Philadelphia he participated in weekly radio shows, edited the zoo's publications, and made frequent television appearances. During this time he also helped establish the Philadelphia Herpetological Society, served as President of the Association of Zoological Parks and Aquariums, and as President of the American Association of Ichthyologists and Herpetologists. In 1947 Roger married Isabelle Hunt Conant, an accomplished photographer and illustrator who had been working at the zoo for several years, and during the following two decades the couple made several collecting trips to Mexico. Roger's first of 240 scientific publications (including 12 books) came at the age of 19; about a decade later he authored *The Reptiles of Ohio*, a landmark

book that set the standard for state herpetological publications. Roger perhaps is best known as the author of the best selling book in herpetological history, *A Field Guide to the Reptiles and Amphibians of Eastern North America*, which was illustrated by Isabelle. The book was published in 1958, and expanded versions followed in 1975, 1991, and 1998. For the majority of amphibian and reptile enthusiasts and herpetologists living in the eastern part of the United States during those years, this book became their bible. In 1973, Roger retired early from the Philadelphia Zoo, after Isabelle had become ill. The Conants then moved to Albuquerque, where Roger became an adjunct professor at the University of New Mexico and devoted much of his time to herpetology. Isabelle passed away in 1976, and soon after Roger discovered that his close friend, Howard K. Gloyd, was terminally ill. Howard had been busy working on a project that he and Roger started in 1932, and because of Howard's deteriorating condition Roger made an enormous commitment and assured Howard that the project would be completed. This hugely important contribution, entitled *Snakes of the Agkistrodon Complex: a Monographic Review*, was published by the Society for the Study of Amphibians and Reptiles (SSAR) in 1990. During this time Roger also was busy writing his memoirs, *A Field Guide to the Life and Times of Roger Conant*, which was published in 1997 by Selva, and details his remarkable life and illustrious career.



Roger Conant in Santa Rosa National Park, Costa Rica (1982).

Louis W. Porras and Gordon W. Schuett, two very close friends of Roger's, were involved at several levels with the *Agkistrodon* monograph and Roger's autobiography. Because of their mutual interest in *Agkistrodon*, in January of 1982 the trio traveled to Costa Rica in search of cantils and although no individuals were found in the

field, they managed to secure preserved specimens for study. In July of that year, Porras returned to Costa Rica with John Rindfleisch and collected what became the holotype of *Agkistrodon bilineatus howardgloydi*. Additional information on the life of Roger Conant appears in an obituary published in the June 2004 issue of *Herpetological Review*. Among several solicited tributes indicating how Roger had affected his colleague's lives and careers, Porras wrote the following summary:

As a giant in herpetology, no doubt many will be writing about Roger Conant's amazing organizational skills, attention to detail, literary contributions, lifelong productivity, and so on. From a personal perspective, however, Roger was my friend, mentor, and father figure. He enriched my life in so many ways, and it would warm his heart to know that by simply following his example, he will continue to do so.

Schuett summarized his tribute as follows:

In reflection, I have no doubt that Roger Conant possessed genius. His was not displayed in eccentric mannerisms and arrogant actions, but in a subtle and quiet ability to collect, organize, and process information for large-scale projects. In his research, each and every detail was painstakingly considered. Roger's vast achievements are even more remarkable knowing that he was largely self-educated. If genius is measured by the degree to which one's ideas and work influence others, Roger stands among the giants of knowledge...Cheers to you, Roger, to your remarkable and enviable life.

Yes, Indeed!

Aurelio Ramírez-Bautista was born in Xalapa, Veracruz, Mexico, and today is a professor and biological investigator at the Universidad Autónoma del Estado de Hidalgo. Dr. Ramírez-Bautista has authored or co-authored more than 100 publications, including five books and 40 book chapters, made numerous presentations on the ecology and conservation of the Mexican herpetofauna, and has become one of the leading herpetologists in the country. During his many years as an educator and researcher, Dr. Ramírez-Bautista advised numerous bachelor, master, and doctoral students. Vicente Mata-Silva met Dr. Ramírez-Bautista in the summer of 1998, as an undergraduate student working on his thesis on the herpetofauna of a portion of the state of Puebla. They developed a friendship, and through Dr. Ramirez-Bautista's mentoring Vicente developed a passion for Mexican herpetology, especially Chihuahuan Desert reptiles, that continued throughout his undergraduate studies and later through master's, doctoral, and post-doctoral work in the Ecology and Evolutionary Biology program at the University of Texas at El Paso. They have continued to work on significant research projects on the conservation and ecology of the Mexican herpetofauna. Vicente is extremely grate-



Aurelio Ramírez-Bautista in Chamela, Jalisco (2011).

ful to Dr. Ramírez-Bautista for his farsighted and life-altering introduction to herpetology. Their association has led to a lifetime friendship, and a road of excitement and opportunities that Vicente never envisioned possible. Dr. Ramírez-Bautista is the epitome of what an educator and mentor should be, providing students the opportunity to become professional scientists working in a world sorely in need of commitment to environmental sustainability.



Hobart M. Smith in Mexico (1930).

Hobart Muir Smith (September 26, 1912–March 4, 2013) was born Frederick William Stouffer in Stanwood, Iowa, USA. At the age of four, he was adopted by Charles and Frances Smith; both of his adoptive parents died, however, before Dr. Smith finished college at Kansas State University (KSU). In the engaging “historical perspective” written by David Chiszar, Edwin McConkey,

and Margaret M. Stewart and published in the 2004(2) issue of *Copeia*, the authors recount an amazing story indicating that when Dr. Smith (HMS) was in his senior year in high school he was plagued by tachycardia and an allergy to caffeine, which ended his interest in running and led to youthful resolution that they reported as follows: “If I’m gonna do anything worthwhile, I had better get to it, because I not gonna live very long” (!). Upon completing high school, he headed for KSU with expectations of a major in entomology. A fortunate meeting with Howard K. Gloyd, a somewhat older student who was majoring in herpetology, brought HMS a change of heart, however, and he became determined to study amphibians and reptiles. He made this decision after having traveled to the American West on collecting trips with Dr. Gloyd, whose association with Dr. Conant is discussed above. Gloyd and his major professor at the University of Michigan, Dr. Frank Blanchard, suggested that HMS contact Edward H. Taylor at the University of Kansas (KU). As noted by Chiszar et al. (2004: 419), “this was probably the act that cinched HMS to a herpetological orientation and kiboshed entomology.” In fact, these authors also claim that “HMS literally collected his BA and moments later hopped into Taylor’s car bound for Mexico,” and that “the rest is history.”



Hobart M. Smith and Rozella B. Smith at the University of Wyoming (1960).

In 1940 (Wilson’s birth year), at age 26, he married Rozella Pearl Beverly Blood, who he met while both were graduate students at KU. Their marriage endured until Rozella’s death in 1987. Dr. Smith began working in Mexico in 1932, before any of the SMI contributors was born, and those early collecting trips instilled a life-long dedication for studying the Mexican herpetofauna. Other collecting ventures followed during the remainder of the decade. The material assembled during these trips allowed him to begin a life-long journey to record the composition, distribution, and systematics of the amazing

Mexican herpetofauna. During his long life he authored more than 1,600 publications, including 29 books—the greatest output in the history of herpetology. Chiszar et al. (2004: 421–422) indicated that HMS was most proud of the three Mexican checklists, the *Sceloporus* monograph, the *Handbook of Lizards*, the comparative anatomy textbook (which Wilson used when he took the course under HMS), the *Synopsis of the Herpetofauna of Mexico*, the *Pliocercus* book, and the *Candoia* monograph. In 1947, HMS became a professor of zoology at the University of Illinois at Urbana-Champaign, and remained there until 1968. During this period in his career, one of the SMI contributors came under his influence. In 1958, Larry David Wilson graduated from Stephen Decatur High School in Decatur, Illinois, and the following year enrolled at Millikin University in that city. After two years and having exhausted the coursework offered by the biology department at Millikin, Wilson decided to move to the U of I, which became a turning point in his life. There, he met HMS and managed to survive a number of his courses, including comparative anatomy. During the two years that led to his graduation, Wilson cemented his interest in zoology and, due to Smith’s influence, decided to attend graduate school and major in herpetology. Also, due to Smith’s interest in Mesoamerican amphibians and reptiles, Wilson was determined to specialize in studying these creatures, and in 1962 ventured south and never returned to live in the flatlands of the “Great Corn Desert.” In 1983, Wilson had the opportunity to acknowledge his gratitude to the Smiths by organizing a symposium on the Mexican herpetofauna in their honor, which was held in connection with the annual SSAR meeting in Salt Lake City, Utah. Although much of Wilson’s overall work has focused on the Honduran herpetofauna, this special issue on the Mexican herpetofauna provided him with an opportunity to reawaken his love for the country where his fieldwork outside the US began in 1966, and to again acknowledge his debt to Dr. Hobart Muir Smith, one of the most important people in the history of herpetology. As Wilson stated in a tribute to HMS on his centenary published last year in *Herpetological Review*, “I know I am only one of many people who are indebted to Dr. Smith in ways small and large. For me, however, his influence determined the direction of my career and, in a significant way, the nature of the contributions I have made to our field.”

Acknowledgments.—The authors of the papers comprising the Special Mexico Issue are very grateful to Sally Nadvornik, who kindly supplied the photographs we used of her father, Hobart M. Smith, and Uriel Hernández-Salinas, who helpfully provided the image we used of Aurelio Ramírez-Bautista. Louis Porras provided the photographs of Roger Conant. The image of Miguel Álvarez del Toro was taken from the 3rd edition of his book, *Los Reptiles de Chiapas*.



Xenosaurus tzacualtipantecus. The Zacualtipán knob-scaled lizard is endemic to the Sierra Madre Oriental of eastern Mexico. This medium-large lizard (female holotype measures 188 mm in total length) is known only from the vicinity of the type locality in eastern Hidalgo, at an elevation of 1,900 m in pine-oak forest, and a nearby locality at 2,000 m in northern Veracruz (Woolrich-Piña and Smith 2012). *Xenosaurus tzacualtipantecus* is thought to belong to the northern clade of the genus, which also contains *X. newmanorum* and *X. platyceps* (Bhullar 2011). As with its congeners, *X. tzacualtipantecus* is an inhabitant of crevices in limestone rocks. This species consumes beetles and lepidopteran larvae and gives birth to living young. The habitat of this lizard in the vicinity of the type locality is being deforested, and people in nearby towns have created an open garbage dump in this area. We determined its EVS as 17, in the middle of the high vulnerability category (see text for explanation), and its status by the IUCN and SEMAR-NAT presently are undetermined. This newly described endemic species is one of nine known species in the monogeneric family Xenosauridae, which is endemic to northern Mesoamerica (Mexico from Tamaulipas to Chiapas and into the montane portions of Alta Verapaz, Guatemala). All but one of these nine species is endemic to Mexico. *Photo by Christian Berriozabal-Islas.*

A conservation reassessment of the reptiles of Mexico based on the EVS measure

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Abstract.—Mexico is the country with the most significant herpetofaunal diversity and endemism in Mesoamerica. Anthropogenic threats to Mexico’s reptiles are growing exponentially, commensurate with the rate of human population growth and unsustainable resource use. In a broad-based multi-authored book published in 2010 (*Conservation of Mesoamerican Amphibians and Reptiles*; CMAR), conservation assessment results differed widely from those compiled in 2005 by IUCN for a segment of the Mexican reptile fauna. In light of this disparity, we reassessed the conservation status of reptiles in Mexico by using the Environmental Vulnerability Score (EVS), a measure previously used in certain Central American countries that we revised for use in Mexico. We updated the total number of species for the Mexican reptile fauna from that reported in CMAR, which brought the new number to 849 (three crocodilians, 48 turtles, and 798 squamates). The 2005 assessment categorized a small percentage of species in the IUCN threat categories (Critically Endangered, Endangered, and Vulnerable), and a large number of species in the category of Least Concern. In view of the results published in CMAR, we considered their approach overoptimistic and reevaluated the conservation status of the Mexican reptile fauna based on the EVS measure. Our results show an inverse (rather than a concordant) relationship between the 2005 IUCN categorizations and the EVS assessment. In contrast to the 2005 IUCN categorization results, the EVS provided a conservation assessment consistent with the threats imposed on the Mexican herpetofauna by anthropogenic environmental degradation. Although we lack corroborative evidence to explain this inconsistency, we express our preference for use of the EVS measure. Based on the results of our analysis, we provide eight recommendations and conclusions of fundamental importance to individuals committed to reversing the trends of biodiversity decline and environmental degradation in the country of Mexico.

Key words. EVS, lizards, snakes, crocodilians, turtles, IUCN categories, IUCN 2005 Mexican Reptile Assessment

Resumen.—México es el país que contiene la diversidad y endemismo de herpetofauna más significativo en Mesoamérica. Las amenazas antropogénicas a los reptiles de México crecen exponencialmente acorde con la tasa de crecimiento de la población humana y el uso insostenible de los recursos. Un libro publicado por varios autores en 2010 (*Conservation of Mesoamerican Amphibians and Reptiles*; CMAR) produjo resultados sobre conservación ampliamente contrarios a los resultados de una evaluación de un segmento de los reptiles mexicanos conducida en 2005 por la UICN. A la luz de esta disparidad, se realizó una nueva evaluación del estado de conservación de los reptiles mexicanos utilizando una medida llamada el Cálculo de Vulnerabilidad Ambiental (EVS), revisado para su uso en México. Se actualizó el número de especies de reptiles mexicanos más allá del estudio de CMAR, por lo que el número total de especies se incrementó a 849 (tres cocodrilos, 48 tortugas, y 798 lagartijas y serpientes). La evaluación de 2005 de la UICN clasificó una proporción inesperadamente pequeña de especies en las categorías para especies amenazadas (En Peligro Crítico, En Peligro, y Vulnerable) y un porcentaje respectivamente grande en la categoría de Preocupación Menor. En vista de los resultados publicados en CMAR, consideramos que los resultados de este enfoque son demasiado optimistas, y reevaluamos el estado de conservación de todos los reptiles mexicanos basándonos en la medida de EVS. Nuestros resultados muestran una relación inversa (más que concordante) entre las categorizaciones de la UICN 2005 y EVS. Contrario a los resultados de las categorizaciones de la UICN 2005, la medida de EVS proporcionó una evaluación para la conservación de reptiles mexicanos que es coherente con las amenazas impuestas por la degradación antropogénica del medio ambiente. No tenemos la evidencia necesaria para proporcionar una explicación para esta inconsistencia, pero expresamos las razones de nuestra preferencia por el uso de los resultados del EVS. A la luz de los resultados de nuestro análisis, hemos

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construido ocho recomendaciones y conclusiones de importancia fundamental para las personas comprometidas en revertir las tendencias asociadas con la pérdida de biodiversidad y la degradación del medio ambiente.

Palabras claves. EVS, lagartijas, culebras, cocodrilos, tortugas, categorías de UICN, 2005 UICN valoración de reptiles mexicanos

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The history of civilization is a history of human beings as they become increasingly knowledgeable about biological diversity.

Beattie and Ehrlich 2004: 1.

Introduction

From a herpetofaunal standpoint, Mexico is the most significant center of diversity in the biodiversity hotspot of Mesoamerica (Mexico and Central America; sensu Wilson and Johnson [2010]). Of the 1,879 species of amphibians and reptiles listed by Wilson and Johnson (2010) for all of Mesoamerica, 1,203 (64.0%) occur in Mexico; reptiles are especially diverse in this country, with 830 species (72.3%) of the 1,148 species distributed throughout Mesoamerica.

Wilson and Johnson (2010) also reported that the highest level of herpetofaunal endemism in Mesoamerica is found in Mexico (66.8% for amphibians, 57.2% for reptiles [60.2% combined]), with the next highest level in Honduras (36.2% for amphibians, 19.2% for reptiles [25.3% combined]). The reported level of herpetofaunal diversity and endemism in Mexico has continued to increase, and below we discuss the changes that have occurred since the publication of Wilson et al. (2010).

Interest in herpetofaunal diversity and endemism in Mexico dates back nearly four centuries (Johnson 2009). Herpetologists, however, only have become aware of the many threats to the survival of amphibian and reptile populations in the country relatively recently. The principal driver of these threats is human population growth (Wilson and Johnson 2010), which is well documented as exponential. “Any quantity that grows by a fixed percent at regular intervals is said to possess exponential growth” (www.regentsprep.org). This characteristic predicts that any population will double in size depending on the percentage growth rate. Mexico is the 11th most populated country in the world (2011 Population Reference Bureau World Population Data Sheet), with an estimated mid-2011 total of 114.8 million people. The population of Mexico is growing at a more rapid rate (1.4% rate of natural increase) than the global average (1.2%), and at a 1.4% rate of natural increase this converts to a doubling time of 50 years ($70/1.4 = 50$). Thus, by the year 2061 the population of Mexico is projected to reach about 230

million, and the population density will increase from 59 to 118/km² (2011 PBR World Population Data Sheet).

Given the widely documented threats to biodiversity posed by human population growth and its consequences (Chiras 2009; Raven et al. 2011), as well as the increasing reports of amphibian population declines in the late 1980s and the 1990s (Blaustein and Wake 1990; Wake 1991), the concept of a Global Amphibian Assessment (GAA) originated and was described as “a first attempt to assess all amphibians against the IUCN Red List Categories and Criteria” (Stuart et al. 2010). The results of this assessment were startling, and given broad press coverage (Conservation International 2004; Stuart et al. 2004). Stuart et al. (2010) reported that of the 5,743 species evaluated, 1,856 were globally threatened (32.3%), i.e., determined to have an IUCN threat status of Critically Endangered (CR), Endangered (EN), or Vulnerable (VU). An additional 1,290 (22.5%) were judged as Data Deficient (DD), i.e., too poorly known for another determinable status. Given the nature of the Data Deficient category, eventually these species likely will be judged in one of the threat categories (CR, EN, or VU). Thus, by adding the Data Deficient species to those determined as globally threatened, the total comes to 3,146 species (54.8% of the world’s amphibian fauna known at the time of the GAA). Our knowledge of the global amphibian fauna has grown since the GAA was conducted, and a website (AmphibiaWeb) arose in response to the realization that more than one-half of the known amphibian fauna is threatened globally or too poorly known to conduct an evaluation. One of the functions of this website is to track the increasing number of amphibian species on a global basis. On 8 April 2013 we accessed this website, and found the number of amphibian species at 7,116, an increase of 23.9% over the number reported in Stuart et al. (2010).

As a partial response to the burgeoning reports of global amphibian population decline, interest in the conservation status of the world’s reptiles began to grow (Gibbons et al. 2000). Some of this interest was due to the recognition that reptiles constitute “an integral part of natural ecosystems and [...] heralds of environmental quality,” just like amphibians (Gibbons et al. 2000: 653). Unfortunately, Gibbons et al. (2000: 653) concluded that, “reptile species are declining on a global scale,” and further (p. 662) that, “the declines of many reptile populations are similar to those experienced by amphibians in



Dermatemys mawii. The Central American river turtle is known from large river systems in Mexico, from central Veracruz southward into Tabasco and Chiapas and northeastward into southwestern Campeche and southern Quintana Roo, avoiding the northern portion of the Yucatan Peninsula. In Central America, it occurs in northern Guatemala and most of Belize. The EVS of this single member of the Mesoamerican endemic family Dermatemyidae has been calculated as 17, placing it in the middle of the high vulnerability category, and the IUCN has assessed this turtle as Critically Endangered. This image is of an individual emerging from its egg, with its egg tooth prominently displayed. The hatching took place at the Zoológico Miguel Álvarez del Toro in Tuxtla Gutiérrez, Chiapas, as part of a captive breeding program for this highly threatened turtle. The parents of this hatchling came from the hydrologic system of the Río Usumacinta and Playas de Catazajá. *Photo by Antonio Ramírez Velázquez.*



Terrapene mexicana. The endemic Mexican box turtle is distributed from southern Tamaulipas southward to central Veracruz and westward to southeastern San Luis Potosí. Its EVS has been determined as 19, placing it in the upper portion of the high vulnerability category, but this turtle has not been evaluated by IUCN. This individual is from Gómez Farias, Tamaulipas, within the Reserva de la Biósfera El Cielo. *Photo by Elí García Padilla.*

terms of taxonomic breadth, geographic scope, and severity.” They also identified the following significant threats to reptile populations: habitat loss and degradation, introduced invasive species, environmental pollution, disease [and parasitism], unsustainable use, and global climate change. Essentially, these are the same threats identified by Vitt and Caldwell (2009) in the Conservation Biology chapter of their textbook *Herpetology*.

In the closing chapter of *Conservation of Mesoamerican Amphibians and Reptiles*, Wilson and Townsend (2010: 774–777) provided six detailed and intensely critical recommendations for the conservation of the herpetofauna of this region, based on the premise that “problems created by humans ... are not solved by treating only their symptoms.” Because of the nature of these recommendations, we consider it important to note that the IUCN conducted a conservation assessment of the Mexican reptiles in 2005, for which the results were made available in 2007 (see NatureServe Press Release, 12 September 2007 at www.natureserve.org). The contents of this press release were startling and unexpected, however, as indicated by its title, “New Assessment of North American Reptiles Finds Rare Good News,” and contrast the conclusions of Wilson and Townsend (2010), which were based on the entire herpetofauna of Mesoamerica. The principal conclusion of the press release was that “a newly completed assessment of the conservation status of North American reptiles shows that most of the group is faring better than expected, with relatively few species at severe risk of extinction.” Wilson and Townsend (2010: 773) commented, however, that “conserving the Mesoamerican herpetofauna will be a major challenge for conservation biologists, in part, because of the large number of species involved and the considerable number that are endemic to individual countries, physiographic regions, and vegetation zones.”

Given the contrast in the conclusions of these two sources, and because the 2005 Mexican reptile assessment was based on the IUCN categories and criteria without considering other measures of conservation status, herein we undertake an independent reassessment of the reptile fauna of Mexico based on the Environmental Vulnerability Score (EVS), a measure developed by Wilson and McCranie (2004) for use in Honduras, which was applied to the herpetofauna of certain Central American countries in Wilson et al. (2010), and modified in this paper for use in Mexico.

The IUCN System of Conservation Status Categorization

The 2005 Mexican reptile assessment was conducted using the IUCN system of conservation status categorization. This system is used widely in conservation biology and applied globally, and particulars are found at the IUCN Red List of Threatened Species website (www.iucnredlist.org). Specifically, the system is elaborated in

the online document entitled “IUCN Red List of Categories and Criteria” (2010), and consists of nine categories, identified and briefly defined as follows (p. 9):

Extinct (EX): “A taxon is Extinct when there is no reasonable doubt that the last individual has died.”

Extinct in the Wild (EW): “A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range.”

Critically Endangered (CR): “A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.”

Endangered (EN): “A taxon is Endangered when the best available evidence indicated that it meets any of the criteria A to E for Endangered, and is therefore considered to be facing a very high risk of extinction in the wild.”

Vulnerable (VU): “A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild.”

Near Threatened (NT): “A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered, or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

Least Concern (LC): “A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.”

Data Deficient (DD): “A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.”

Not Evaluated (NE): “A taxon is Not Evaluated when it has not yet been evaluated against the criteria.”

As noted in the definition of the Near Threatened category, the Critically Endangered, Endangered, and Vulnerable categories are those with a threat of extinction in the wild. A lengthy discussion of criteria A to E mentioned in the definitions above is available in the 2010 IUCN document.

A Revised EVS for Mexico

In this paper, we revised the design of the EVS for Mexico, which differs from previous schemes in the components of geographic distribution and human persecution.

Initially, the EVS was designed for use in instances where the details of a species’ population status (upon



Trachemys gaigeae. The Big Bend slider is distributed along the Rio Grande Valley in south-central New Mexico and Texas, as well as in the Río Conchos system in Chihuahua. Its EVS has been calculated as 18, placing it in the upper portion of the high vulnerability category, and the IUCN has assessed this turtle as Vulnerable. This individual is from the Rio Grande about 184 straight kilometers SE of Ciudad Juarez, Chihuahua. Although the picture was taken on the US side (about 44 km SSW of Van Horn, Hudspeth County, Texas), it was originally in the water. *Photo by Vicente Mata-Silva.*



Kinosternon oaxacae. The endemic Oaxaca mud turtle occurs in southern Oaxaca and adjacent eastern Guerrero. Its EVS has been estimated as 15, placing it in the lower portion of the high vulnerability category, and the IUCN considers this kinosternid as Data Deficient. This individual was found in riparian vegetation along the edge of a pond in La Soledad, Tututepec, Oaxaca. *Photo by Vicente Mata-Silva.*

which many of the criteria for the IUCN status categorizations depend) are not available, so as to estimate its susceptibility to future environmental threats. In this regard, the EVS usually can be calculated as soon as a species is described, as it depends on information generally available when the species is discovered. Use of the EVS, therefore, does not depend on population assessments, which often are costly and time consuming. Nonetheless, its use does not preclude the implementation of other measures for assessing the conservation status of a species, when these measures can be employed. After all, conservation assessment measures are only a guide for designing conservation strategies, and constitute an initial step in our effort to protect wildlife.

The version of the EVS algorithm we developed for use in Mexico consists of three scales, for which the values are added to produce the Environmental Vulnerability Score. The first scale deals with geographic distribution, as follows:

- 1 = distribution broadly represented both inside and outside Mexico (large portions of range are both inside and outside Mexico)
- 2 = distribution prevalent inside Mexico, but limited outside Mexico (most of range is inside Mexico)
- 3 = distribution limited inside Mexico, but prevalent outside Mexico (most of range is outside Mexico)
- 4 = distribution limited both inside and outside Mexico (most of range is marginal to areas near border of Mexico and the United States or Central America)
- 5 = distribution only within Mexico, but not restricted to vicinity of type locality
- 6 = distribution limited to Mexico in the vicinity of type locality

The second scale deals with ecological distribution based on the number of vegetation formations occupied, as follows:

- 1 = occurs in eight or more formations
- 2 = occurs in seven formations
- 3 = occurs in six formations
- 4 = occurs in five formations
- 5 = occurs in four formations
- 6 = occurs in three formations
- 7 = occurs in two formations
- 8 = occurs in one formation

The third scale relates to the degree of human persecution (a different measure is used for amphibians), as follows:

- 1 = fossorial, usually escape human notice
- 2 = semifossorial, or nocturnal arboreal or aquatic, nonvenomous and usually non-mimicking, sometimes escape human notice
- 3 = terrestrial and/or arboreal or aquatic, generally ignored by humans
- 4 = terrestrial and/or arboreal or aquatic, thought to be harmful, might be killed on sight
- 5 = venomous species or mimics thereof, killed on sight
- 6 = commercially or non-commercially exploited for hides, meat, eggs and/or the pet trade

The score for each of these three components is added to obtain the Environmental Vulnerability Score, which can range from 3 to 20. Wilson and McCranie (2004) divided the range of scores for Honduran reptiles into three categories of vulnerability to environmental degradation, as follows: low (3–9); medium (10–13); and high (14–19). We use a similar categorization here, with the high category ranging from 14–20.

For convenience, we utilized the traditional classification of reptiles, so as to include turtles and crocodilians, as well as lizards and snakes (which in a modern context comprise a group).

Recent Changes to the Mexican Reptile Fauna

Our knowledge of the composition of the Mexican reptile fauna keeps changing due to the discovery of new species and the systematic adjustment of certain known species, which adds or subtracts from the list of taxa that appeared in Wilson et al. (2010). Since that time, the following nine species have been described:

Gopherus morafkai: Murphy et al. (2011). *ZooKeys* 113: 39–71.

Anolis unilobatus: Köhler and Vesely (2010). *Herpetologica* 66: 186–207.

Gerrhonotus farri: Bryson and Graham (2010). *Herpetologica* 66: 92–98.

Scincella kikaapoda: García-Vásquez et al. (2010). *Copeia* 2010: 373–381.

Lepidophyma cuicateca: Canseco-Márquez et al. (2008). *Zootaxa* 1750: 59–67.

Lepidophyma zongolica: García-Vásquez et al. (2010). *Zootaxa* 2657: 47–54.

Xenosaurus tzacualtipantecus: Woolrich-Piña and Smith (2012). *Herpetologica* 68: 551–559.

Coniophanes michoacanensis: Flores-Villela and Smith (2009). *Herpetologica* 65: 404–412.

Geophis occabus: Pavón-Vázquez et al. (2011). *Herpetologica* 67: 332–343.



Abronía smithi. Smith's arboreal alligator lizard is endemic to the Sierra Madre de Chiapas, in the southeastern portion of this state. Its EVS has been determined as 17, placing it in the middle of the high vulnerability category; the IUCN, however, lists this lizard as of Least Concern. This individual was found in cloud forest in the Reserva de la Biósfera El Triunfo, Chiapas. *Photo by Elí García-Padilla.*

The following 18 taxa either have been resurrected from the synonymy of other taxa or placed in the synonymy of other taxa, and thus also change the number of species in the CMAR list:

- Phyllodactylus nocticolus*: Blair et al. (2009). *Zootaxa* 2027: 28–42. Resurrected as a distinct species from *P. xanti*.
- Sceloporus albiventris*: Lemos-Espinal et al. (2004). *Bulletin of the Chicago Herpetological Society* 39: 164–168. Resurrected as a distinct species from *S. horridus*.
- Sceloporus bimaculatus*: Leaché and Mulcahy (2007). *Molecular Ecology* 16: 5216–5233. Returned to the synonymy of *S. magister*.
- Plestiodon bilineatus*: Feria-Ortiz et al. (2011). *Herpetological Monographs* 25: 25–51. Elevated to full species from *P. brevirostris*.
- Plestiodon dicei*: Feria-Ortiz et al. (2011). *Herpetological Monographs* 25: 25–51. Elevated to full species from *P. brevirostris*.
- Plestiodon indubitus*: Feria-Ortiz et al. (2011). *Herpetological Monographs* 25: 25–51. Elevated to full species from *P. brevirostris*.
- Plestiodon nietoi*: Feria-Ortiz and García-Vázquez (2012). *Zootaxa* 3339: 57–68. Elevated to full species from *P. brevirostris*.
- Aspidoscelis stictogramma*: Walker and Cordes (2011). *Herpetological Review* 42: 33–39. Elevated to full species from *A. burti*.
- Xenosaurus agrenon*: Bhullar (2011). *Bulletin of the Museum of Comparative Zoology* 160: 65–181. Elevated to full species from *X. grandis*.
- Xenosaurus rackhami*: Bhullar (2011). *Bulletin of the Museum of Comparative Zoology* 160: 65–181. Elevated to full species from *X. grandis*.
- Lampropeltis californiae*: Pyron and Burbrink (2009). *Zootaxa* 2241: 22–32. Elevated to full species from *L. getula*.
- Lampropeltis holbrooki*: Pyron and Burbrink (2009). *Zootaxa* 2241: 22–32. Elevated to full species from *L. getula*.
- Lampropeltis splendida*: Pyron and Burbrink (2009). *Zootaxa* 2241: 22–32. Elevated to full species from *L. getula*.
- Sonora aequalis*: Cox et al. (2012). *Systematics and Biodiversity* 10: 93–108. Placed in synonymy of *S. mutabilis*.
- Coniophanes taylori*: Flores-Villela and Smith (2009). *Herpetologica* 65: 404–412. Resurrected as a distinct species from *C. piceivittis*.
- Leptodeira maculata*: Daza et al. (2009). *Molecular Phylogenetics and Evolution* 53: 653–667. Synonymized with *L. cussiliris*. The correct name of the taxon, however, contrary to the decision of Daza et al. (2009), is *L. maculata*, inasmuch as this name

was originated by Hallowell in 1861, and thus has priority. *Leptodeira cussiliris*, conversely, originally was named as a subspecies of *L. annulata* by Duellman (1958), and thus becomes a junior synonym of *L. maculata*.

Crotalus ornatus: Anderson and Greenbaum (2012). *Herpetological Monographs* 26: 19–57. Resurrected as a distinct species from the synonymy of *C. molossus*.

Mixcoatlus browni: Jadin et al. (2011). *Zoological Journal of the Linnean Society* 163: 943–958. Resurrected as a distinct species from *M. barbouri*.

The following species have undergone status changes, including some taxa discussed in the addendum to Wilson and Johnson (2010):

- Anolis beckeri*: Köhler (2010). *Zootaxa* 2354: 1–18. Resurrected as a distinct species from *A. pentapri- on*, which thus no longer occurs in Mexico.
- Marisora brachypoda*: Hedges and Conn (2012). *Zootaxa* 3288: 1–244. Generic name originated for a group of species formerly allocated to *Mabuya*.
- Sphaerodactylus continentalis*: McCranie and Hedges (2012). *Zootaxa* 3492: 65–76. Resurrection from synonymy of *S. millepunctatus*, which thus no longer occurs in Mexico.
- Holcosus chaitzami*, *H. festivus*, and *H. undulatus*: Harvey et al. (2012). *Zootaxa* 3459: 1–156. Generic name originated for a group of species formerly allocated to *Ameiva*.
- Lampropeltis knoblochi*: Burbrink et al. (2011). *Molecular and Phylogenetic Evolution*. 60: 445–454. Elevated to full species from *L. pyromelana*, which thus no longer is considered to occur in Mexico.
- Leptodeira cussiliris*: Mulcahy. 2007. *Biological Journal of the Linnean Society* 92: 483–500. Removed from synonymy of *L. annulata*, which thus no longer occurs in Mexico. See *Leptodeira maculata* entry above.
- Leptodeira uribei*: Reyes-Velasco and Mulcahy (2010). *Herpetologica* 66: 99–110. Removed from the genus *Pseudoleptodeira*.
- Rhadinella godmani*: Myers. 2011. *American Museum Novitates* 3715: 1–33. Species placed in new genus from *Rhadinaea*.
- Rhadinella hannsteini*: Myers (2011). *American Museum Novitates* 3715: 1–33. Species placed in new genus from *Rhadinaea*.
- Rhadinella kanalchutchan*: Myers (2011). *American Museum Novitates* 3715: 1–33. Species placed in new genus from *Rhadinaea*.
- Rhadinella kinkelini*: Myers (2011). *American Museum Novitates* 3715: 1–33. Species placed in new genus from *Rhadinaea*.



Barisia ciliaris. The widespread Sierra alligator lizard is endemic to Mexico, and is part of a complex that still is undergoing systematic study. Its distribution extends along the Sierra Madre Occidental from southern Chihuahua southward through western Durango and into central Jalisco, and thence into northern Guanajuato and central Querétaro and northward in the Sierra Madre Oriental to central Nuevo León. Its EVS has been calculated as 15, placing it in the lower portion of the high vulnerability category. The IUCN does not recognize this taxon at the species level, so it has to be considered as Not Evaluated. This individual is from 10.1 km WNW of La Congoja, Aguascalientes. *Photo by Louis W. Porras.*



Lampropeltis mexicana. The endemic Mexican gray-banded kingsnake is distributed from the Sierra Madre Occidental in southern Durango and the Sierra Madre Oriental in extreme southeastern Coahuila southward to northern Guanajuato. Its EVS has been gauged as 15, placing it in the lower portion of the high vulnerability category, but its IUCN status, however, was determined as of Least Concern. This individual was found at Banderas de Aguila (N of Coyotes), Durango. *Photo by Ed Cassano.*

- Rhadinella lachrymans*: Myers (2011). *American Museum Novitates* 3715: 1–33. Species placed in new genus from *Rhadinaea*.
- Rhadinella posadasi*: Myers (2011). *American Museum Novitates* 3715: 1–33. Species placed in new genus from *Rhadinaea*.
- Rhadinella schistosa*: Myers (2011). *American Museum Novitates* 3715: 1–33. Species placed in new genus from *Rhadinaea*.
- Sonora aemula*: Cox et al. (2012). *Systematics and Biodiversity* 10: 93–108. Generic name changed from *Procinura*, which thus becomes a synonym of *Sonora*.
- Epictia goudotii*: Adalsteinsson et al. (2009). *Zootaxa* 2244: 1–50. Species placed in a new genus from *Leptotyphlops*.
- Rena boettgeri*: Adalsteinsson et al. (2009). *Zootaxa* 2244: 1–50. Species placed in a new genus from *Leptotyphlops*.
- Rena bressoni*: Adalsteinsson et al. (2009). *Zootaxa* 2244: 1–50. Species placed in a new genus from *Leptotyphlops*.
- Rena dissecta*: Adalsteinsson et al. (2009). *Zootaxa* 2244: 1–50. Species placed in a new genus from *Leptotyphlops*.
- Rena dulcis*: Adalsteinsson et al. (2009). *Zootaxa* 2244: 1–50. Species placed in a new genus from *Leptotyphlops*.
- Rena humilis*: Adalsteinsson et al. (2009). *Zootaxa* 2244: 1–50. Species placed in a new genus from *Leptotyphlops*.
- Rena maxima*: Adalsteinsson et al. (2009). *Zootaxa* 2244: 1–50. Species placed in a new genus from *Leptotyphlops*.
- Rena myopica*: Adalsteinsson et al. (2009). *Zootaxa* 2244: 1–50. Species placed in a new genus from *Leptotyphlops*.
- Mixcoatlus barbouri*: Jadin et al. (2011). *Zoological Journal of the Linnean Society* 163: 943–958. New genus for species removed from *Cerrophidion*.
- Mixcoatlus melanurus*: Jadin et al. (2011). *Zoological Journal of the Linnean Society* 163: 943–958. New genus for species removed from *Ophryacus*.

Results of the 2005 Mexican Reptile Assessment

The 2005 Mexican Reptile Assessment “was carried out by zoologists from the non-profit conservation group NatureServe, working in partnership with reptile experts from universities, the World Conservation Union (IUCN), and Conservation International” (NatureServe Press Release; available at natureserve.org/aboutUS/PressReleases). This study dealt with “721 species of lizards and snakes found in Mexico, the United States, and Canada.” Turtles and crocodilians previously were assessed. The press release indicated that, “about one

in eight lizards and snakes (84 species) were found to be threatened with extinction [i.e., judged as Critically Endangered, Endangered, or Vulnerable], with another 23 species labeled Near Threatened. For 121 lizards and snakes, the data are insufficient to allow a confident estimate of their extinction risk [i.e., judged as Data Deficient], while 493 species (about two-thirds of the total) are at present relatively secure [i.e., judged as Least Concern].” Thus, the percentages of species that fall into the standard IUCN assessment categories are as follows: CR, EN, and VU (11.7); NT (3.2); DD (16.8); and LC (68.4).

Inasmuch as the above results include species that occur in the United States, Canada, and also those not evaluated in the survey, we extracted information from the IUCN Red List website on the ratings provided for Mexican species alone, and also used the “NE” designation for species not included in the 2005 assessment. We list these ratings in Appendix 1.

Critique of the 2005 Results

Our primary reason for writing this paper is to critique the results of the Mexican reptile assessment, as reported in the above press release, and to reassess the conservation status of these organisms using another conservation assessment tool. We begin our critique with the data placed in Appendix 1, which we accessed at the IUCN Red List website up until 26 May 2012. The taxa listed in this appendix are current to the present, based on the changes to the Mexican reptile fauna indicated above. The data on the IUCN ratings are summarized by family in Table 1 and discussed below.

We based our examination on the understanding that the word “critique” does not necessarily imply an unfavorable evaluation of the results of the Mexican reptile assessment, as conducted using the IUCN categories and criteria. “Critique,” in the strict sense, implies neither praise nor censure, and is neutral in context. We understand, however, that the word sometimes is used in a negative sense, as noted in the 3rd edition of *The American Heritage Dictionary* (1992: 443). Nonetheless, our usage simply means to render a careful analysis of the results.

Presently, we recognize 849 species of reptiles in Mexico, including three crocodilians, 48 turtles, 413 lizards and amphisbaenians, and 385 snakes, arrayed in 42 families. This total represents an increase of 19 species (14 lizards, five snakes) over the totals listed by Wilson and Johnson (2010). The number and percentage of each of these 849 species allocated to the IUCN categories, or not evaluated, are as follows: CR = 9 (1.1%); EN = 38 (4.5%); VU = 45 (5.3%); NT = 26 (3.1%); LC = 424 (49.9%); DD = 118 (13.9%); and NE (not evaluated) = 189 (22.2%). The number and percentage of species collectively allocated to the three threat categories (CR, EN, and VU) are 92 and 10.8%, respectively. This number is exceeded by the 118 species placed in the DD category, and is slightly less than one-half of the 189 species not



Anolis dollfusianus. The coffee anole is distributed on the Pacific versant from southern Chiapas to western Guatemala. Its EVS has been determined as 13, placing it at the upper end of the medium vulnerability category, and its IUCN status is undetermined. This individual was found in cloud forest in Reserva de la Biósfera El Triunfo, Chiapas. *Photo by Elí García-Padilla.*

Table 1. IUCN Red List categorizations for the Mexican reptile families (including crocodilians, turtles, lizards, and snakes).

Families	Number of species	IUCN Red List categorizations						
		Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Alligatoridae	1	—	—	—	—	1	—	—
Crocodylidae	2	—	—	1	—	1	—	—
Subtotals	3	—	—	1	—	2	—	—
Cheloniidae	5	2	2	1	—	—	—	—
Chelydridae	1	—	—	1	—	—	—	—
Dermatemydidae	1	1	—	—	—	—	—	—
Dermochelyidae	1	1	—	—	—	—	—	—
Emydidae	15	—	2	4	2	2	1	4
Geoemydidae	3	—	—	—	2	—	—	1
Kinosternidae	17	—	—	—	6	6	3	2
Testudinidae	3	1	—	1	—	1	—	1
Trionychidae	2	—	—	—	—	1	—	1
Subtotals	48	4	4	7	10	10	4	8
Biporidae	3	—	—	—	—	3	—	—
Anguidae	48	—	10	4	1	17	10	9
Anniellidae	2	—	1	—	—	1	—	—
Corytophanidae	6	—	—	—	—	1	—	5
Crotaphytidae	10	—	1	1	—	8	—	—
Dactyloidae	50	—	3	2	—	16	12	17
Dibamidae	1	—	—	—	—	1	—	—
Eublepharidae	7	—	—	—	—	6	—	1
Gymnophthalmidae	1	—	—	—	—	—	—	1
Helodermatidae	2	—	—	—	1	1	—	—
Iguanidae	19	1	—	2	2	3	—	11
Mabuyidae	1	—	—	—	—	—	—	1
Phrynosomatidae	135	1	5	8	6	89	6	20
Phyllodactylidae	15	—	—	—	1	10	1	3
Scincidae	23	—	—	1	—	12	5	5
Sphaerodactylidae	4	—	—	—	—	—	—	4
Sphenomorphidae	6	—	—	—	—	3	—	3
Teiidae	40	—	—	3	1	35	2	5
Xantusiidae	25	—	1	2	—	9	4	8
Xenosauridae	9	—	2	1	—	2	1	3
Subtotals	413	2	23	24	12	214	45	93
Boidae	2	—	—	—	—	1	—	1
Colubridae	136	2	3	1	3	77	18	32
Dipsadidae	115	—	3	3	—	44	38	27
Elapidae	19	—	—	1	—	13	4	1
Leptotyphlopidae	8	—	—	—	—	5	1	2
Loxocemidae	1	—	—	—	—	—	—	1
Natricidae	33	—	2	3	—	20	3	5
Typhlopidae	2	—	—	—	—	2	—	—
Ungaliophiidae	2	—	—	1	—	—	—	1
Viperidae	59	1	3	4	1	33	4	13
Xenodontidae	8	—	—	—	—	3	1	4
Subtotals	385	3	11	13	4	198	69	87
Totals	849	9	38	45	26	424	118	189



Mastigodryas cliftoni. The endemic Clifton's lizard eater is found along the Pacific versant from extreme southeastern Sonora southward to Jalisco. Its EVS has been determined as 14, placing it at the lower end of the high vulnerability category, and its IUCN status has not been assessed. This individual is from El Carrizo, Sinaloa. *Photo by Ed Cassano.*



Geophis dugesi. The endemic Dugès' earthsnake occurs from extreme southwestern Chihuahua along the length of the Sierra Madre Occidental southward to Michoacán. Its EVS has been assessed as 13, placing it at the upper end of the medium vulnerability category, and its IUCN status has been determined as of Least Concern. This individual was found at El Carrizo, Sinaloa. *Photo by Ed Cassano.*

evaluated on the website. Thus, of the total of 849 species, 307 (36.2%) are categorized either as DD or NE. As a consequence, only 542 (63.8%) of the total number are allocated to one of the other five categories (CR, EN, VU, NT, or LC).

These results provided us with a substantially incomplete picture of the conservation status of reptiles in Mexico, which sharply contrasts the picture offered for Central American reptiles (the other major portion of Mesoamerica), as recorded in Wilson et al. (2010). This situation is underscored by the relatively low species numbers of Mexican reptiles placed in any of the three IUCN threat categories. In addition, a substantial proportion (13.9%) of the Mexican species are assessed as DD, indicating that insufficient information exists for the IUCN rating system to be employed. Finally, 189 species (22.3%) are not evaluated, largely because they also occur in Central America (and in some cases, also in South America) and will be assessed presumably in future workshops, which was the case for most of these species when they were assessed in a Central American workshop held on May 6–10, 2012; as yet, the results of that assessment are not available.

Given that only 10.8% of the Mexican species were allocated to one of the three IUCN threat categories and that about six in 10 species in the country are endemic, we examined the IUCN ratings reported for species inhabiting five of the countries in Central America (see Wilson et al. 2010). For Guatemala, Acevedo et al. (2010) reported that 56 reptile species (23.0%) of a total of 244 then recognized were assigned to one of the three threat categories. Of 237 Honduran reptiles assessed by Townsend and Wilson (2010), 74 (31.2%) were placed in one of the threat categories. Sunyer and Köhler (2010) listed 165 reptile species from Nicaragua, a country with only three endemic reptiles known at the time, but judged 10 of them (6.1%) as threatened. Of 231 reptile species assessed by Sasa et al. (2010) for Costa Rica, 36 (15.6%) were placed in a threat category. Finally, Jaramillo et al. (2010) placed 22 of 248 Panamanian reptile species (8.9%) in the threat categories. Collectively, 17% of the reptile species in these countries were assessed in one of the three threat categories.

The number of species in Central America placed into one of the threat categories apparently is related to the number allocated to the DD category. Although the DD category is stated explicitly as a non-threat category (IUCN Red List Categories and Criteria 2010), its use highlights species so poorly known that one of the other IUCN categories cannot be applied. The percentage of DD species in the reptile faunas of each of the five Central American countries discussed above ranges from 0.9 in Honduras to 40.3 in Panama. Intermediate figures are as follows: Nicaragua = 1.2; Guatemala = 5.3; Costa Rica = 34.2. These data apparently indicate that the conservation status of the Costa Rican and Panamanian reptile

faunas are by far more poorly understood than those of Guatemala, Honduras, and Nicaragua.

The length of time for placing these DD species into another category is unknown, but a reassessment must await targeted surveys for the species involved. Given the uncertainty implied by the use of this category supplemented by that of NE species in Mexico, we believe there is ample reason to reassess the conservation status of the Mexican reptiles using the Environmental Vulnerability Score (EVS).

EVS for Mexican Reptiles

The EVS provides several advantages for assessing the conservation status of amphibians and reptiles. First, this measure can be applied as soon as a species is described, because the information necessary for its application generally is known at that point. Second, the calculation of the EVS is an economical undertaking and does not require expensive, grant-supported workshops, such as those held in connection with the Global Reptile Assessment sponsored by the IUCN. Third, the EVS is predictive, because it provides a measure of susceptibility to anthropogenic pressure, and can pinpoint taxa in need of immediate attention and continuing scrutiny. Finally, this measure is simple to calculate and does not “penalize” species that are poorly known. One disadvantage of the EVS, however, is that it was not designed for use with marine species. So, the six species of marine turtles and two of marine snakes occurring on the shores of Mexico could not be assessed. Nevertheless, given the increasing rates of human population growth and environmental deterioration, an important consideration for a given species is to have a conservation assessment measure that can be applied simply, quickly, and economically.

We calculated the EVS for each of the 841 species of terrestrial reptiles occurring in Mexico (Wilson and Johnson 2010, and updated herein; see Appendix 1). In this appendix, we listed the scores alongside the IUCN categorizations from the 2005 Mexican Reptile Assessment, as available on the IUCN Red List website (www.iucnredlist.org) and as otherwise determined by us (i.e., as NE species).

Theoretically, the EVS can range from 3 to 20. A score of 3 is indicative of a species that ranges widely both within and outside of Mexico, occupies eight or more forest formations, and is fossorial and usually escapes human notice. Only one such species (the leptotyphlopoid snake *Epictia goudotii*) is found in Mexico. At the other extreme, a score of 20 relates to a species known only from the vicinity of the type locality, occupies a single forest formation, and is exploited commercially or non-commercially for hides, meat, eggs and/or the pet trade. Also, only one such species (the trionychid turtle *Apalone atra*) occurs in Mexico. All of the other scores fall within the range of 4–19. We summarized the EVS for reptile species in Mexico by family in Table 2.



Rhadinaea laureata. The endemic crowned graceful brownsnake is distributed along the Sierra Madre Occidental from west-central Durango southward into the Transverse Volcanic Axis as far as central Michoacán, Morelos, and the Distrito Federal. Its EVS has been calculated as 12, placing it in the upper portion of the medium vulnerability category, and its IUCN status has been determined as Least Concern. This individual is from Rancho Las Canoas, Durango. *Photo by Louis W. Porras.*



Thamnophis mendax. The endemic Tamaulipan montane gartersnake is restricted to a small range in the Sierra Madre Oriental in southwestern Tamaulipas. Its EVS has been determined as 14, placing it at the lower end of the high vulnerability category, and its IUCN status has been assessed as Endangered. This individual came from La Gloria, in the Gómez Farías region of Tamaulipas. *Photo by Ed Cassano.*

Table 2. Environmental Vulnerability Scores for the Mexican reptile species (including crocodilians, turtles, lizards, and snakes, but excluding the marine species), arranged by family. Shaded area to the left encompasses low vulnerability scores, and to the right high vulnerability scores.

Families	Number of species	Environmental Vulnerability Scores																	
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Alligatoridae	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Crocodylidae	2	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—
Subtotals	3	—	—	—	—	—	—	—	—	—	—	1	1	—	1	—	—	—	—
Subtotal %	—	—	—	—	—	—	—	—	—	—	—	33.3	33.3	—	33.3	—	—	—	—
Chelydridae	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Dermatemydidae	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Emydidae	15	—	—	—	—	—	—	—	—	—	—	1	1	1	2	1	4	5	—
Geoemydidae	3	—	—	—	—	—	1	—	—	—	—	1	1	—	—	—	—	—	—
Kinosternidae	17	—	—	—	—	—	—	—	3	1	1	1	6	3	2	—	—	—	—
Testudinidae	3	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	1	—
Trionychidae	2	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Subtotals	42	—	—	—	—	—	1	—	3	1	1	3	8	6	4	3	5	6	1
Subtotal %	—	—	—	—	—	—	2.4	—	7.1	2.4	2.4	7.1	19.0	14.3	9.5	7.1	11.9	14.3	2.4
Bipedidae	3	—	—	—	—	—	—	—	—	—	1	—	2	—	—	—	—	—	—
Anguidae	48	—	—	—	1	—	—	1	2	—	1	3	6	11	7	8	8	—	—
Anniellidae	2	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—
Corytophanidae	6	—	—	—	—	1	1	1	—	2	—	1	—	—	—	—	—	—	—
Crotaphytidae	10	—	—	—	—	—	—	1	—	1	2	2	—	—	4	—	—	—	—
Dactyloidae	50	—	—	—	—	—	2	—	—	—	3	8	—	8	15	4	—	—	—
Dibamidae	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eublepharidae	7	—	—	—	—	—	—	1	—	1	—	—	2	1	—	1	1	—	—
Gymnophthalmidae	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Helodermatidae	2	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—
Iguanidae	19	—	—	—	—	—	1	—	—	1	2	1	1	4	4	2	1	2	—
Mabuyidae	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phrynosomatidae	135	—	—	1	1	2	1	3	3	11	18	22	16	23	23	11	—	—	—
Phyllodactylidae	15	—	—	—	—	—	1	—	2	—	—	1	1	4	5	1	—	—	—
Scincidae	23	—	—	—	—	—	—	—	1	4	5	2	4	4	2	1	—	—	—
Sphaerodactylidae	4	—	—	—	—	—	—	—	1	1	1	1	—	—	—	—	—	—	—
Sphenomorphidae	6	—	—	—	—	1	1	—	—	1	1	1	—	—	—	1	—	—	—
Teiidae	46	—	—	—	—	—	2	—	—	2	2	—	14	—	8	—	—	—	—
Xantusiidae	25	—	—	—	—	—	2	—	—	2	1	3	4	3	9	1	—	—	—
Xenosauridae	9	—	—	—	—	—	—	1	—	1	1	—	1	1	3	1	—	—	—
Subtotals	413	—	—	1	3	6	11	13	14	28	39	49	54	67	78	38	10	2	—
Subtotal %	—	—	—	0.2	0.7	1.5	2.7	3.1	3.4	6.8	9.4	11.9	13.1	16.2	18.9	9.2	2.4	0.5	—
Boidae	2	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—

Table 2. Continued.

Colubridae	136	—	—	4	7	3	6	10	15	8	8	18	22	14	16	5	—	—	—
Dipsadidae	115	—	1	3	3	3	8	4	7	6	13	14	13	19	15	6	—	—	—
Elapidae	17	—	—	—	—	—	2	—	—	2	—	2	2	3	—	2	3	1	—
Leptotyphlopidae	8	1	—	—	—	—	1	—	—	2	—	2	2	—	—	—	—	—	—
Loxocemidae	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Natricidae	33	—	—	—	—	3	1	—	2	2	2	3	6	7	4	2	1	—	—
Typhlopidae	2	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—
Ungaliophiidae	2	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—
Viperidae	59	—	—	—	—	—	1	2	1	3	7	5	6	6	9	8	5	6	—
Xenodontidae	8	—	—	—	—	—	—	1	1	1	—	3	1	—	—	1	—	—	—
Subtotals	383	1	1	7	10	9	19	17	30	25	31	47	52	50	44	24	9	7	—
Subtotal %	—	0.3	0.3	1.8	2.6	2.3	5.0	4.4	7.8	6.5	8.1	12.3	13.6	13.1	11.5	6.3	2.3	1.8	—
Totals	841	1	1	8	13	15	31	30	47	54	71	100	115	123	127	65	24	15	1
Total %	—	0.1	0.1	1.0	1.5	1.8	3.7	3.6	5.6	6.4	8.4	11.9	13.7	14.6	15.1	7.7	2.9	1.8	0.1

The range and average EVS for the major reptile groups are as follows: crocodilians = 13–16 (14.3); turtles = 8–20 (15.3); lizards = 5–19 (13.8); and snakes = 3–19 (12.8). On average, turtles are most susceptible and snakes least susceptible to environmental degradation, with lizards and crocodilians falling in between. The average scores either are at the upper end of the medium category, in the case of snakes and lizards, or at the lower end of the high category, in the case of crocodilians and turtles. The average EVS for all the reptile species is 13.4, a value close to the lower end of the high range of vulnerability.

Nineteen percent of the turtle species were assigned an EVS of 14, at the lower end of the high vulnerability category. For lizards, the respective figures are 18.9% and 16, about midway through the range for the high vulnerability category; for snakes, the values are 13.6% and 14.

The total EVS values generally increase from the low end of the scale (3) to about midway through the high end (16), with a single exception (a decrease from 31 to 29 species at scores 8 and 9), then decrease thereafter to the highest score (20). The peak number of taxa (127) was assigned an EVS of 16, a score that falls well within the range of high vulnerability.

Of the 841 total taxa that could be scored, 99 (11.8%) fall into the low vulnerability category, 272 (32.3%) in the medium category, and 470 (55.9%) in the high category. Thus, more than one-half of the reptile species in Mexico were judged as having the highest degree of vulnerability to environmental degradation, and slightly more than one-tenth of the species the lowest degree.

This increase in absolute and relative numbers from the low portion, through the medium portion, to the high portion varies somewhat with the results published for both the amphibians and reptiles for some Central American countries (see Wilson et al. 2010). Acevedo et al.

(2010) reported 89 species (23.2%) with low scores, 179 (46.7%) with medium scores, and 115 (30.0%) with high scores for Guatemala. The same trend is seen in Honduras, where Townsend and Wilson (2010) indicated the following absolute and relative figures in the same order, again for both amphibians and reptiles: 71 (19.7%); 169 (46.8%); and 121 (33.5%). Comparable figures for the Panamanian herpetofauna (Jaramillo et al. 2010) are: 143 (33.3%); 165 (38.4%); and 122 (28.4%).

The principal reason that EVS values are relatively high in Mexico is because of the high level of endemism and the relatively narrow range of habitat occurrence. Of the 485 endemic species in Mexico (18 turtles, 264 lizards, 203 snakes), 124 (25.6%) were assigned a geographic distribution score of 6, signifying that these creatures are known only from the vicinity of their respective type localities; the remainder of the endemic species (361 [74.4%]) are more broadly distributed within the country (Appendix 1). Of the 841 terrestrial Mexican reptile species, 212 (25.2%) are limited in ecological distribution to one formation (Appendix 1). These features of geographic and ecological distribution are of tremendous significance for efforts at conserving the immensely important Mexican reptile fauna.

Comparison of IUCN Categorizations and EVS Values

Since the IUCN categorizations and EVS values both measure the degree of environmental threat impinging on a given species, a certain degree of correlation between the results of these two measures is expected. Townsend and Wilson (2010) demonstrated this relationship with reference to the Honduran herpetofauna, by comparing the IUCN and EVS values for 362 species of amphibians and terrestrial reptiles in their table 4. Perusal of the data in this table indicates, in a general way, that an increase in



Crotalus catalinensis. The endemic Catalina Island rattlesnake is restricted in distribution to Santa Catalina Island in the Gulf of California. Its EVS has been determined as 19, placing it in the upper portion of the high vulnerability category, and its IUCN status as Critically Endangered. Photo by Louis W. Porras.



Crotalus stejnegeri. The endemic Sinaloan long-tailed rattlesnake is restricted to a relatively small range in western Mexico, where it is found in the western portion of the Sierra Madre Occidental in western Durango and southeastern Sinaloa. Its EVS has been determined as 17, placing it in the middle of the high vulnerability category, and its IUCN status as Vulnerable. This individual came from Plomosas, Sinaloa. Photo by Louis W. Porras.

Table 3. Comparison of the Environmental Vulnerability Scores (EVS) and IUCN categorizations for terrestrial Mexican reptiles. Shaded area on top encompasses the low vulnerability category scores, and at the bottom high vulnerability category scores.

EVS	IUCN categories							Totals
	Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Data Deficient	Not Evaluated	
3	—	—	—	—	—	—	1	1
4	—	—	—	—	1	—	—	1
5	—	—	—	—	3	—	5	8
6	—	—	—	—	5	—	8	13
7	—	—	—	—	5	—	10	15
8	—	—	—	—	20	—	11	31
9	—	—	1	—	16	—	13	30
10	—	—	—	—	25	1	21	47
11	—	—	1	1	36	2	14	54
12	—	1	1	—	49	4	16	71
13	—	2	5	3	66	5	19	100
14	—	5	6	8	65	15	16	115
15	—	13	11	7	54	25	13	123
16	—	8	3	6	48	38	24	127
17	4	3	11	1	21	14	11	65
18	—	2	2	—	4	12	4	24
19	2	2	3	—	4	2	2	15
20	—	—	—	—	—	—	1	1
Totals	6	36	44	26	422	118	189	841

EVS values is associated with a corresponding increase in the degree of threat, as measured by the IUCN categorizations. If average EVS values are determined for the IUCN categories in ascending degrees of threat, the following figures result: LC (206 spp.) = 10.5; NT (16 spp.) = 12.9; VU (18 spp.) = 12.5; EN (64 spp.) = 14.1; CR (50 spp.) = 15.1; and EX (2 spp.) = 16.0. The broad correspondence between the two measures is evident. Also of interest is that the average EVS score for the six DD species listed in the table is 13.7, a figure closest to that for the EN category (14.1), which suggests that if and when these species are better known, they likely will be judged as EN or CR.

In order to assess whether such a correspondence exists between these two conservation measures for the Mexican reptiles, we constructed a table (Table 3) similar to table 4 in Townsend and Wilson (2010). Important similarities and differences exist between these tables. The most important similarity is in general appearance, i.e., an apparent general trend of decreasing EVS values with a decrease in the degree of threat, as indicated by the IUCN categorizations. This similarity, however, is more apparent than real. Our Table 3 deals only with Mexican reptiles, excludes the IUCN category EX (because presently this category does not apply to any Mexican species), and includes a NE category that we appended to the standard set of IUCN categories. Apart from these obvious differences, however, a closer examination of

the data distribution in our Table 3 reveals more significant differences in the overall picture of the conservation status of the Mexican reptiles when using the IUCN categorizations, as opposed to the EVS, especially when viewed against the backdrop of results in Townsend and Wilson (2010: table 4).

1. Nature of the IUCN categorizations in Table 3

Unlike the Townsend and Wilson (2010) study, we introduced another category to encompass the Mexican reptile species that were not evaluated in the 2005 IUCN study. The category is termed “Not Evaluated” (IUCN 2010) and a large proportion of the species (189 of 841 Mexican terrestrial reptiles [22.5%]) are placed in this category. Thus, in the 2005 study more than one-fifth of the species were not placed in one of the standard IUCN categories, leaving their conservation status as undetermined. In addition, a sizable proportion of species (118 [14.0%]) were placed in the DD category, meaning their conservation status also remains undetermined. When the species falling into these two categories are added, evidently 307 (36.5%) of the 841 Mexican terrestrial reptiles were not placed in one of the IUCN threat assessment categories in the 2005 study. This situation leaves less than two-thirds of the species as evaluated.



Xantusia sanchezi. The endemic Sanchez's night lizard is known only from extreme southwestern Zacatecas to central Jalisco. This lizard's EVS has been assessed as 16, placing it in the middle of the high vulnerability category, but its IUCN status has been determined as Least Concern. This individual was discovered at Huaxtla, Jalisco. *Photo by Daniel Cruz-Sáenz.*

2. Pattern of mean EVS vs. IUCN categorizations

In order to more precisely determine the relationship between the IUCN categorizations and the EVS, we calculated the mean EVS for each of the IUCN columns in Table 3, including the NE species and the total species. The results are as follows: CR (6 spp.) = 17.7 (range 17–19); EN (36 spp.) = 15.4 (12–19); VU (44 spp.) = 15.3 (10–19); NT (26 spp.) = 14.6 (11–17); LC (422 spp.) = 13.0 (4–19); DD (118 spp.) = 15.5 (10–19); and NE (189 spp.) = 12.0 (3–20); and Total (841 spp.) = 13.3 (3–20). The results of these data show that the mean EVS decreases from the CR category (17.7) through the EN category (15.4) to the VU category (15.3), but only slightly between the EN and VU categories. They also continue to decrease from the NT category (14.6) to the LC category (13.0). This pattern of decreasing values was expected. In addition, as with the Townsend and Wilson (2010) Honduran study, the mean value for the DD species (15.5) is closest to that for the EN species (15.4). To us, this indicates what we generally have suspected about the DD category, i.e., that the species placed in this category likely will fall either into the EN or the CR categories when (and if) their conservation status is better understood. Placing species in this category is of little benefit to determining their conservation status, however, since once sequestered with this designation their significance tends to be downplayed. This situation prevailed once the results of the 2005 assessment were reported, given that the 118 species evaluated as DD were ignored in favor of the glowing report that emerged in the NatureServe press release (see above). If the data in Table 3 for the DD species is conflated with that for the 86 species placed in one of the three threat categories, the range of EVS values represented remains the same as for the threat categories alone, i.e., 10–19, and the mean becomes 15.5; the same as that indicated above for the DD species alone and only one-tenth of a point from the mean score for EN species (15.4). On the basis of this analysis, we predict that if a concerted effort to locate and assess the 118 DD species were undertaken, that most or all of them would be shown to qualify for inclusion in one of the three IUCN threat categories. If that result were obtained, then the number of Mexican reptile species falling into the IUCN threat categories would increase from 86 to 204, which would represent 24.3% of the reptile fauna.

Based on the range and mean of the EVS values, the pattern for the LC species appears similar to that of the NE species, as the ranges are 4–19 and 3–20 and the means are 13.0 and 12.0, respectively. If these score distributions are conflated, then the EVS range becomes the broadest possible (3–20) and the mean becomes 12.7, which lies close to the upper end of the medium vulnerability category. While we cannot predict what would happen to the NE species once they are evaluated (presumably most species were evaluated during the Central

American reptile assessment of May, 2012), because they were evaluated mostly by a different group of herpetologists from those present at the 2005 Mexican assessment, we suspect that many (if not most) would be judged as LC species. A more discerning look at both the LC and NE species might demonstrate that many should be partitioned into other IUCN categories, rather than the LC. Our reasoning is that LC and NE species exhibit a range of EVS values that extend broadly across low, medium, and high categories of environmental vulnerability. The number and percentage of LC species that fall into these three EVS categories are as follows: Low (range 3–9) = 50 spp. (11.8%); Medium (10–13) = 176 (41.7%); and High (14–20) = 196 (46.5%). For the NE species, the following figures were obtained: Low = 48 (25.8%); Medium = 68 (36.6%); and High = 70 (37.6%). The percentage values are reasonably similar to one another, certainly increasing in the same direction from low through medium to high.

Considering the total number of species, 99 (11.8%) fall into the low vulnerability category, 272 (32.3%) into the medium vulnerability category, and 470 (55.9%) into the high vulnerability category. These results differ significantly from those from the 2005 study. If the three IUCN threat categories can be considered most comparable to the high vulnerability EVS category, then 86 species fall into these three threat categories, which is 16.1% of the total 534 species in the CR, EN, VU, NT, and LC categories. If the NT category can be compared with the medium vulnerability EVS category, then 26 species fall into this IUCN category (4.9% of the 534 species). Finally, if the LC category is comparable to the low vulnerability EVS category, then 422 species (79.0%) fall into this IUCN category. Clearly, the results of the EVS analysis are nearly the reverse of those obtained from the IUCN categorizations discussed above.

Discussion

In the Introduction we indicated that our interest in conducting this study began after the publication of Wilson et al. (2010), when we compared the data resulting from that publication with a summary of the results of a 2005 Mexican reptile assessment conducted under the auspices of the IUCN, and later referenced in a 2007 press release by NatureServe, a supporter of the undertaking. Our intention was not to critique the IUCN system of conservation assessment (i.e., the well-known IUCN categorizations), but rather to critique the results of the 2005 assessment. We based our critique on the use of the Environmental Vulnerability Score (EVS), a measure used by Wilson and McCranie (2004) and in several Central American chapters in Wilson et al. (2010).

Since the IUCN assessment system uses a different set of criteria than the EVS measure, we hypothesized that the latter could be used to test the results of the former. On this basis, we reassessed the conservation status

of the reptiles of Mexico, including, by our definition of convenience, crocodilians, turtles, lizards, and snakes, by determining the EVS value for each terrestrial species (since the measure was not designed for use with marine species). Based on our updating of the species list in Wilson and Johnson (2010), our species list for this study consisted of 841 species. We then developed an EVS measure applicable to Mexico, and employed it to calculate the scores indicated in Appendix 1.

Our analysis of the EVS values demonstrated that when the scores are arranged in low, medium, and high vulnerability categories, the number and percentage of species increases markedly from the low category, through the medium category, to the high category (Table 2). When these scores (Table 3) are compared to the IUCN categorizations documented in Table 1, however, an inverse correlation essentially exists between the results obtained from using the two methods. Since both methods are designed to render conservation status assessments, the results would be expected to corroborate one another.

We are not in a position to speculate on the reason(s) for this lack of accord, and simply are offering a reassessment of the conservation status of Mexico's reptile species based on another measure (EVS) that has been used in a series of studies since it was introduced by Wilson and McCranie (1992), and later employed by McCranie and Wilson (2002), Wilson and McCranie (2004), and several chapters in Wilson et al. (2010). Nonetheless, we believe our results provide a significantly better assessment of the conservation status Mexico's reptiles than those obtained in the 2005 IUCN assessment. We consider our results more consonant with the high degree of reptile endemism in the country, and the restricted geographic and ecological ranges of a sizable proportion of these species. We also believe that our measure is more predictive, and reflective of impact expected from continued habitat fragmentation and destruction in the face of continuing and unregulated human population growth.

Conclusions and Recommendations

Our conclusions and conservation recommendations draw substantially from those promulgated by Wilson and Townsend (2010), which were provided for the entire Mesoamerican herpetofauna; thus, we refined them specifically for the Mexican reptile fauna, as follows:

1. In the introduction we noted the human population size and density expected for Mexico in half a century, and no indication is available to suggest that this trend will be ameliorated. Nonetheless, although 66% of married women in Mexico (ages 15–49) use modern methods of contraception, the current fertility rate (2.3) remains above the replacement level (2.0) and 29% of the population is below the age of 15, 1% above the average for Latin America and the Caribbean (2011 PRB World Population Data Sheet).
2. Human population growth is not attuned purposefully to resource availability, and the rate of regeneration depends on the interaction of such societal factors as the level of urbanization; in Mexico, the current level is 78%, and much of it centered in the Distrito Federal (2011 PRB World Population Data Sheet). This statistic is comparable to that of the United States (79%) and Canada (80%), and indicates that 22% of Mexico's population lives in rural areas. Given that the level of imports and exports are about equal (in 2011, imports = 350.8 billion US dollars, exports = 349.7 billion; CIA World Factbook 2012), the urban population depends on the basic foodstuffs that the rural population produces. An increase in human population demands greater agricultural production and/or efficiency, as well as a greater conversion of wild lands to farmlands. This scenario leads to habitat loss and degradation, and signals an increase in biodiversity decline.
3. Although the rate of conversion of natural habitats to agricultural and urban lands varies based on the methods and assumptions used for garnering this determination, most estimates generally are in agreement. The Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT; Secretariat of Environment and Natural Resources; semarnat.gob.mx) has attempted to measure the rate of deforestation from 1978 to 2005, with estimates ranging from about 200,000 to 1,500,000 ha/yr. Most estimates, however, range from about 200,000 to 400,000 ha/yr. A study conducted for the years 2000 to 2005 reported an average rate of 260,000 ha/yr. Another source of information (www.rainforests.mongabay.com) reports that from 1990 to 2010 Mexico lost an average of 274,450 ha (0.39% of the total 64,802,000 ha of forest in the country), and during that period lost 7.8% of its forest cover (ca. 5,489,000 ha). No matter the precise figures for forest loss, this alarming situation signifies considerable endangerment for organismic populations, including those of reptiles. About one-third of Mexico is (or was) covered by forest, and assuming a constant rate of loss all forests would be lost in about 256 years (starting from 1990), or in the year 2246. Forest loss in Mexico, therefore, contributes significantly to the global problem of deforestation.
4. As a consequence, no permanent solution to the problem of biodiversity decline (including herpetofaunal decline) will be found in Mexico (or elsewhere in the world) until humans recognize overpopulation as the major cause of degradation and loss of humankind's fellow organisms. Although this problem is beyond the scope of this investigation, solutions will not be

available until humanity begins to realize the origin, nature, and consequences of the mismatch between human worldviews and how our planet functions. Wilson (1988) labeled this problem “the mismanagement of the human mind.” Unfortunately, such realignment is only envisioned by a small cadre of humans, so crafting provisional solutions to problems like biodiversity decline must proceed while realizing the ultimate solution is not available, and might never be.

5. Mexico is the headquarters of herpetofaunal diversity and endemism in Mesoamerica, which supports the conclusions of Ochoa-Ochoa and Flores-Villela (2006), Wilson and Johnson (2010), and the authors of four chapters on the Mexican herpetofauna in Wilson et al. (2010). Furthermore, field research and systematic inquiry in Mexico will continue to augment the levels of diversity and endemism, which are of immense conservation significance because reptiles are significant contributors to the proper functioning of terrestrial and aquatic ecosystems (Gibbons et al. 2000). From a political and economic perspective, diversity and endemism are important components of Mexico’s patrimony, as well as a potential source of income from ecotourism and related activities. Investing in such income sources should appeal to local stakeholders, as it provides an incentive for preserving natural habitats (Wilson 2011).
6. Given that the ultimate solutions to biodiversity decline are unlikely to be implemented in any pertinent time frame, less effective solutions must be found. Vitt and Caldwell (2009) discussed a suite of approaches for preserving and managing threatened species, including the use of reserves and corridors to save habitats, undertaking captive management initiatives, and intentionally releasing individuals to establish or enlarge populations of target species. Unquestionably, preserving critical habitat is the most effective and least costly means of attempting to rescue threatened species. Captive management is less effective, and has been described as a last-ditch effort to extract a given species from the extinction vortex (Campbell et al. 2006). Efforts currently are underway in segments of the herpetological community to develop programs for ex situ and in situ captive management of some of the most seriously threatened herpetofaunal species, but such efforts will succeed only if these species can be reproduced in captivity and reintroduced into their native habitats. In the case of Mexico, Ochoa-Ochoa, et al. (2011: 2710) commented that, “given the current speed of land use change, we cannot expect to save all species from extinction, and so must decide how to focus limited resources to prevent the greatest number of extinctions,” and for amphibians proposed “a simple conservation triage method that: evaluates the threat status for 145 micro-

endemic Mexican amphibian species; assesses current potential threat abatement responses derived from existing policy instruments and social initiatives; and combines both indicators to provide broad-scale conservation strategies that would best suit amphibian micro-endemic buffered areas (AMBAs) in Mexico.” These authors concluded, however, that a quarter of the micro-endemic amphibians “urgently need field-based verification to confirm their persistence due to the small percentage of remnant natural vegetation within the AMBAs, before we may sensibly recommend” a conservation strategy. Their tool also should apply to Mexican reptiles, and likely would produce similar results.

7. The preferred method for preserving threatened species is to protect habitats by establishing protected areas, both in the public and private sectors. Habitat protection allows for a nearly incalculable array of relationships among organisms. Like most countries in the world, Mexico, has developed a governmentally established system of protected areas. Fortunately, studies have identified “critical conservation zones” (Ceballos et al. 2009), as well as gaps in their coverage (Koleff et al. 2009). The five reserves of greatest conservation importance for reptiles are the Los Tuxtlas Biosphere Reserve, the islands of the Gulf of California in the UNESCO World Heritage Site, the Sierra Gorda Biosphere Reserve, the Tehuacán-Cuicatlán Biosphere Reserve, and the Chamela-Cuixmala Biosphere Reserve. Significantly, all of these areas are part of the UNESCO World Network of Biosphere Reserves, but attainment of this status does not guarantee that these reserves will remain free from anthropogenic damage. Ceballos et al. (2009, citing Dirzo and García 1992) indicated that although the Los Tuxtlas is the most important reserve in Mexico for amphibians and reptiles, a large part of its natural vegetation has been lost. This example of deforestation is only one of many, but led Ceballos et al. (2009: 597) to conclude (our translation of the original Spanish) that, “The determination of high risk critical zones has diverse implications for conservation in Mexico. The distribution of critical zones in the entire country confirms the problem of the loss of biological diversity is severe at the present time, and everything indicates it will become yet more serious in future decades. On the other hand, the precise identification of these zones is a useful tool to guide political decisions concerning development and conservation in the country, and to maximize the effects of conservation action. Clearly, a fundamental linchpin for the national conservation strategy is to direct resources and efforts to protect the high-risk critical zones. Finally, it also is evident that tools for management of production and development, such as the land-use planning and environmental impact, should be reinforced in order to

fully comply with their function to reconcile development and conservation.” We fully support this recommendation.

8. Humans have developed an amazing propensity for living in an unsustainable world. Organisms only can persist on Earth when they live within their environmental limiting factors, and their strategy is sustainability, i.e., in human terms, living over the long term within one’s means, a process made allowable by organic evolution. *Homo sapiens* is the only extant species with the capacity for devising another means for securing its place on the planet, i.e., a strategy of unsustainability over the short term, which eventually is calculated to fail. Conservation biology exists because humans have devised this unworkable living strategy. What success it will have in curbing biodiversity loss remains to be seen.

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Appendix 1. Comparison of the IUCN Ratings from the 2005 Mexican Assessment (updated to the present time) and the Environmental Vulnerability Scores for 849 Mexican reptile species (crocodilians, turtles, lizards, and snakes). See text for explanation of the IUCN and EVS rating systems. * = species endemic to Mexico. ¹ = IUCN status needs updating. ² = Not rated because not recognized as a distinct species. ³ = not described at the time of assessment.

Species	IUCN Ratings	Environmental Vulnerability Scores			
		Geographic Distribution	Ecological Distribution	Degree of Human Persecution	Total Score
Order Crocodylia (3 species)					
Family Alligatoridae (1 species)					
<i>Caiman crocodilus</i>	LC ¹	3	7	6	16
Family Crocodylidae (2 species)					
<i>Crocodylus acutus</i>	VU	3	5	6	14
<i>Crocodylus moreletii</i>	LC	2	5	6	13
Order Testudines (48 species)					
Family Cheloniidae (5 species)					
<i>Caretta caretta</i>	EN	—	—	—	—
<i>Chelonia mydas</i>	EN	—	—	—	—
<i>Eretmochelys imbricata</i>	CR	—	—	—	—
<i>Lepidochelys kempii</i>	CR	—	—	—	—
<i>Lepidochelys olivacea</i>	VU	—	—	—	—
Family Chelydridae (1 species)					
<i>Chelydra rossignonii</i>	VU	4	7	6	17
Family Dermatemydidae (1 species)					
<i>Dermatemys mawii</i>	CR	4	7	6	17
Family Dermochelyidae (1 species)					
<i>Dermochelys coriacea</i>	CR	—	—	—	—
Family Emydidae (15 species)					
<i>Actinemys marmorata</i>	VU	3	8	6	17
<i>Chrysemys picta</i>	LC	3	8	3	14
<i>Pseudemys gorzugi</i>	NT	4	6	6	16
<i>Terrapene coahuila</i> *	EN	5	8	6	19
<i>Terrapene mexicana</i> *	NE	5	8	6	19
<i>Terrapene nelsoni</i> *	DD	5	7	6	18
<i>Terrapene ornata</i>	NT	3	6	6	15
<i>Terrapene yucatana</i> *	NE	5	7	6	18
<i>Trachemys gaigeae</i>	VU	4	8	6	18
<i>Trachemys nebulosa</i> *	NE	5	7	6	18
<i>Trachemys ornata</i> *	VU	5	8	6	19
<i>Trachemys scripta</i>	LC	3	7	6	16
<i>Trachemys taylori</i> *	EN	5	8	6	19
<i>Trachemys venusta</i>	NE	3	4	6	13
<i>Trachemys yaquia</i> *	VU	5	8	6	19
Family Geoemydidae (3 species)					
<i>Rhinoclemmys areolata</i>	NT	4	6	3	13
<i>Rhinoclemmys pulcherrima</i>	NE	1	4	3	8
<i>Rhinoclemmys rubida</i> *	NT	5	6	3	14
Family Kinosternidae (17 species)					
<i>Claudius angustatus</i>	NT ¹	4	7	3	14
<i>Kinosternon acutum</i>	NT ¹	4	7	3	14

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<i>Kinosternon alamosae</i> *	DD	5	6	3	14
<i>Kinosternon arizonense</i>	LC	4	8	3	15
<i>Kinosternon chimalhuaca</i> *	LC	5	8	3	16
<i>Kinosternon creaseri</i> *	LC	5	7	3	15
<i>Kinosternon durangoense</i> *	DD	5	8	3	16
<i>Kinosternon flavescens</i>	LC	3	6	3	12
<i>Kinosternon herrerae</i> *	NT	5	6	3	14
<i>Kinosternon hirtipes</i>	LC	2	5	3	10
<i>Kinosternon integrum</i> *	LC	5	3	3	11
<i>Kinosternon leucostomum</i>	NE	3	4	3	10
<i>Kinosternon oaxacae</i> *	DD	5	7	3	15
<i>Kinosternon scorpioides</i>	NE	3	4	3	10
<i>Kinosternon sonoriense</i>	NT	4	7	3	14
<i>Staurotypus salvinii</i>	NT ¹	4	6	3	13
<i>Staurotypus triporcatus</i>	NT ¹	4	7	3	14
Family Testudinidae (3 species)					
<i>Gopherus berlandieri</i>	LC ¹	4	8	6	18
<i>Gopherus flavomarginatus</i> *	VU	5	8	6	19
<i>Gopherus morafkai</i>	NE ³	4	5	6	15
Family Trionychidae (2 species)					
<i>Apalone atra</i> *	NE	6	8	6	20
<i>Apalone spinifera</i>	LC	3	6	6	15
Order Squamata (798 species)					
Family Bipedidae (3 species)					
<i>Bipes biporus</i> *	LC	5	8	1	14
<i>Bipes canaliculatus</i> *	LC	5	6	1	12
<i>Bipes tridactylus</i> *	LC	5	8	1	14
Family Anguidae (48 species)					
<i>Abronia bogerti</i> *	DD	6	8	4	18
<i>Abronia chiszari</i> *	EN	6	7	4	17
<i>Abronia deppii</i> *	EN	6	6	4	16
<i>Abronia fuscolabialis</i> *	EN	6	8	4	18
<i>Abronia graminea</i> *	EN	5	6	4	15
<i>Abronia leurolepis</i> *	DD	6	8	4	18
<i>Abronia lythrochila</i> *	LC	6	7	4	17
<i>Abronia martindalcampoi</i> *	EN	5	6	4	15
<i>Abronia matudai</i>	EN	4	7	4	15
<i>Abronia mitchelli</i> *	DD	6	8	4	18
<i>Abronia mixteca</i> *	VU	6	8	4	18
<i>Abronia oaxacae</i> *	VU	6	7	4	17
<i>Abronia ochoterenai</i>	DD	4	8	4	16
<i>Abronia ornelasi</i> *	DD	6	8	4	18
<i>Abronia ramirezi</i> *	DD	6	8	4	18
<i>Abronia reidi</i> *	DD	6	8	4	18
<i>Abronia smithi</i> *	LC	6	7	4	17
<i>Abronia taeniata</i> *	VU	5	6	4	15
<i>Anguis ceroni</i> *	NE	5	7	2	14
<i>Anguis incomptus</i> *	NE	5	8	2	15
<i>Barisia ciliaris</i> *	NE	5	7	3	15

<i>Barisia herrerae</i> *	EN	5	7	3	15
<i>Barisia imbricata</i> *	LC	5	6	3	14
<i>Barisia jonesi</i> *	NE ²	6	7	3	16
<i>Barisia levicollis</i> *	DD	5	7	3	15
<i>Barisia planifrons</i> *	NE ²	5	7	3	15
<i>Barisia rudicollis</i> *	EN	5	7	3	15
<i>Celestus enneagrammus</i> *	LC	5	6	3	14
<i>Celestus ingridae</i> *	DD	6	8	3	17
<i>Celestus legnotus</i> *	LC	5	6	3	14
<i>Celestus rozellae</i>	NT	4	6	3	13
<i>Elgaria cedrosensis</i> *	LC	5	8	3	16
<i>Elgaria kingii</i>	LC	2	5	3	10
<i>Elgaria multicarinata</i>	LC	3	4	3	10
<i>Elgaria nana</i> *	LC	5	8	3	16
<i>Elgaria paucicarinata</i> *	VU	5	5	3	13
<i>Elgaria velazquezi</i> *	LC	5	6	3	14
<i>Gerrhonotus farri</i> *	NE ³	6	8	3	17
<i>Gerrhonotus infernalis</i> *	LC	5	5	3	13
<i>Gerrhonotus liocephalus</i>	LC	2	1	3	6
<i>Gerrhonotus lugoi</i> *	LC	6	8	3	17
<i>Gerrhonotus ophiurus</i> *	LC	5	4	3	12
<i>Gerrhonotus parvus</i> *	EN	6	8	3	17
<i>Mesaspis antauges</i> *	DD	6	7	3	16
<i>Mesaspis gadovii</i> *	LC	5	6	3	14
<i>Mesaspis juarezi</i> *	EN	5	7	3	15
<i>Mesaspis moreleti</i>	LC	3	3	3	9
<i>Mesaspis viridiflava</i> *	LC	5	8	3	16
Family Anniellidae (2 species)					
<i>Anniella geronimensis</i> *	EN	5	7	1	13
<i>Anniella pulchra</i>	LC	3	8	1	12
Family Corytophanidae (6 species)					
<i>Basiliscus vittatus</i>	NE	1	3	3	7
<i>Corytophanes cristatus</i>	NE	3	5	3	11
<i>Corytophanes hernandesii</i>	NE	4	6	3	13
<i>Corytophanes percarinatus</i>	NE	4	4	3	11
<i>Laemactus longipes</i>	NE	1	5	3	9
<i>Laemactus serratus</i>	LC	2	3	3	8
Family Crotaphytidae (10 species)					
<i>Crotaphytus antiquus</i> *	EN	5	8	3	16
<i>Crotaphytus collaris</i>	LC	3	7	3	13
<i>Crotaphytus dickersonae</i> *	LC	5	8	3	16
<i>Crotaphytus grismeri</i> *	LC	5	8	3	16
<i>Crotaphytus insularis</i> *	LC	6	7	3	16
<i>Crotaphytus nebrius</i>	LC	2	7	3	12
<i>Crotaphytus reticulatus</i>	VU	4	5	3	12
<i>Crotaphytus vestigium</i>	LC	3	3	3	9
<i>Gambelia copeii</i>	LC	2	6	3	11
<i>Gambelia wislizenii</i>	LC	3	7	3	13

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Family Dactyloidae (50 species)					
<i>Anolis allisoni</i>	NE	3	7	3	13
<i>Anolis alvarezdeltoroi*</i>	DD	6	8	3	17
<i>Anolis anisolepis*</i>	LC	5	7	3	15
<i>Anolis barkeri*</i>	VU	5	7	3	15
<i>Anolis beckeri</i>	NE ³	3	6	3	12
<i>Anolis biporcatus</i>	NE	3	4	3	10
<i>Anolis breedlovei*</i>	EN	6	7	3	16
<i>Anolis capito</i>	NE	3	6	3	13
<i>Anolis compressicauda*</i>	LC	5	7	3	15
<i>Anolis crassulus</i>	NE	3	4	3	10
<i>Anolis cristifer</i>	DD	4	6	3	13
<i>Anolis cuprinus*</i>	LC	6	7	3	16
<i>Anolis cymbops*</i>	DD	6	8	3	17
<i>Anolis dollfusianus</i>	NE	4	6	3	13
<i>Anolis duellmani*</i>	DD	6	8	3	17
<i>Anolis dunni*</i>	LC	5	8	3	16
<i>Anolis forbesi*</i>	DD	6	7	3	16
<i>Anolis gadovi*</i>	LC	5	8	3	16
<i>Anolis hobartsmithi*</i>	EN	6	6	3	15
<i>Anolis isthmicus*</i>	DD	5	8	3	16
<i>Anolis laeviventris</i>	NE	3	3	3	9
<i>Anolis lemurinus</i>	NE	3	2	3	8
<i>Anolis liogaster*</i>	LC	5	6	3	14
<i>Anolis macrinii*</i>	LC	5	8	3	16
<i>Anolis matudai</i>	NE	4	6	3	13
<i>Anolis megapholidotus*</i>	LC	5	8	3	16
<i>Anolis microlepidotus*</i>	LC	5	7	3	15
<i>Anolis milleri*</i>	DD	5	6	3	14
<i>Anolis naufragus*</i>	VU	5	5	3	13
<i>Anolis nebuloides*</i>	LC	5	6	3	14
<i>Anolis nebulosus*</i>	LC	5	5	3	13
<i>Anolis omiltemanus*</i>	LC	5	7	3	15
<i>Anolis parvicirculatus*</i>	LC	6	7	3	16
<i>Anolis petersii</i>	NE	2	4	3	9
<i>Anolis polyrhachis*</i>	DD	5	8	3	16
<i>Anolis pygmaeus*</i>	EN	5	8	3	16
<i>Anolis quercorum*</i>	LC	5	8	3	16
<i>Anolis rodriguezii</i>	NE	4	3	3	10
<i>Anolis sagrei</i>	NE	2	7	3	12
<i>Anolis schiedii*</i>	DD	5	8	3	16
<i>Anolis schmidtii*</i>	LC	5	8	3	16
<i>Anolis sericeus</i>	NE	2	3	3	8
<i>Anolis serranoi</i>	NE	4	5	3	12
<i>Anolis simmonsii*</i>	DD	5	7	3	15
<i>Anolis subocularis*</i>	DD	5	7	3	15
<i>Anolis taylori*</i>	LC	5	8	3	16
<i>Anolis tropidonotus</i>	NE	4	2	3	9
<i>Anolis uniformis</i>	NE	4	6	3	13

<i>Anolis unilobatus</i>	NE ³	1	3	3	7
<i>Anolis utowanae</i> *	DD	6	8	3	17
Family Dibamidae (1 species)					
<i>Anelytropsis papillosus</i> *	LC	5	4	1	10
Family Eublepharidae (7 species)					
<i>Coleonyx brevis</i>	LC	4	6	4	14
<i>Coleonyx elegans</i>	NE	2	3	4	9
<i>Coleonyx fasciatus</i> *	LC	5	8	4	17
<i>Coleonyx gypsicolus</i> *	LC	6	8	4	18
<i>Coleonyx reticulatus</i>	LC	4	7	4	15
<i>Coleonyx switaki</i>	LC	4	6	4	14
<i>Coleonyx variegatus</i>	LC	4	3	4	11
Family Gymnophthalmidae (1 species)					
<i>Gymnophthalmus speciosus</i>	NE	3	3	3	9
Family Helodermatidae (2 species)					
<i>Heloderma horridum</i>	LC	2	4	5	11
<i>Heloderma suspectum</i>	NT	4	6	5	15
Family Iguanidae (19 species)					
<i>Ctenosaura acanthura</i>	NE	2	4	6	12
<i>Ctenosaura alfredschmidtii</i>	NT	4	8	3	15
<i>Ctenosaura clarki</i> *	VU	5	7	3	15
<i>Ctenosaura conspicuosa</i> *	NE	5	8	3	16
<i>Ctenosaura defensor</i> *	VU	5	7	3	15
<i>Ctenosaura hemilopha</i> *	NE	5	7	6	18
<i>Ctenosaura macrolopha</i> *	NE	5	8	6	19
<i>Ctenosaura nolascensis</i> *	NE	6	8	3	17
<i>Ctenosaura oaxacana</i> *	CR	5	8	6	19
<i>Ctenosaura pectinata</i> *	NE	5	4	6	15
<i>Ctenosaura similis</i>	LC	1	4	3	8
<i>Dipsosaurus catalinensis</i> *	NE	6	8	3	17
<i>Dipsosaurus dorsalis</i>	LC	4	4	3	11
<i>Iguana iguana</i>	NE	3	3	6	12
<i>Sauromalus ater</i>	LC	4	6	3	13
<i>Sauromalus hispidus</i> *	NT	5	6	3	14
<i>Sauromalus klauberi</i> *	NE	6	7	3	16
<i>Sauromalus slevini</i> *	NE	5	8	3	16
<i>Sauromalus varius</i> *	NE	5	8	3	16
Family Mabuyidae (1 species)					
<i>Marisora brachypoda</i>	NE	1	2	3	6
Family Phrynosomatidae (135 species)					
<i>Callisaurus draconoides</i>	LC	4	5	3	12
<i>Cophosaurus texanus</i>	LC	4	7	3	14
<i>Holbrookia approximans</i> *	NE	5	6	3	14
<i>Holbrookia elegans</i>	LC	4	6	3	13
<i>Holbrookia lacerata</i>	NT	4	7	3	14
<i>Holbrookia maculata</i>	LC	1	6	3	10
<i>Holbrookia propinqua</i>	LC	4	8	3	15
<i>Petrosaurus mearnsi</i>	LC	4	5	3	12
<i>Petrosaurus repens</i> *	LC	5	5	3	13

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<i>Petrosaurus slevini</i> *	LC	5	8	3	16
<i>Petrosaurus thalassinus</i> *	LC	5	5	3	13
<i>Phrynosoma asio</i>	NE	2	6	3	11
<i>Phrynosoma blainvillii</i>	NE	3	7	3	13
<i>Phrynosoma braconneri</i> *	LC	5	7	3	15
<i>Phrynosoma cerroense</i> *	NE	6	7	3	16
<i>Phrynosoma cornutum</i>	LC	1	7	3	11
<i>Phrynosoma coronatum</i> *	LC	5	4	3	12
<i>Phrynosoma ditmarsii</i> *	DD	5	8	3	16
<i>Phrynosoma goodei</i>	NE	4	6	3	13
<i>Phrynosoma hernandesi</i>	LC	3	7	3	13
<i>Phrynosoma mcallii</i>	NT	4	8	3	15
<i>Phrynosoma modestum</i>	LC	4	5	3	12
<i>Phrynosoma orbiculare</i> *	LC	5	4	3	12
<i>Phrynosoma platyrhinos</i>	LC	3	7	3	13
<i>Phrynosoma solare</i>	LC	4	7	3	14
<i>Phrynosoma taurus</i> *	LC	5	4	3	12
<i>Phrynosoma wigginsi</i> *	NE	5	8	3	16
<i>Sceloporus acanthinus</i>	NE	3	7	3	13
<i>Sceloporus adleri</i> *	LC	5	7	3	15
<i>Sceloporus aeneus</i> *	LC	5	5	3	13
<i>Sceloporus albiventris</i> *	NE	5	8	3	16
<i>Sceloporus anahuacus</i> *	LC	5	7	3	15
<i>Sceloporus angustus</i> *	LC	5	8	3	16
<i>Sceloporus asper</i> *	LC	5	6	3	14
<i>Sceloporus bicanthalis</i> *	LC	5	5	3	13
<i>Sceloporus bulleri</i> *	LC	5	7	3	15
<i>Sceloporus carinatus</i>	LC	4	5	3	12
<i>Sceloporus cautus</i> *	LC	5	7	3	15
<i>Sceloporus chaneysi</i> *	EN	5	7	3	15
<i>Sceloporus chrysostictus</i>	LC	4	6	3	13
<i>Sceloporus clarkii</i>	LC	2	5	3	10
<i>Sceloporus couchii</i> *	LC	5	7	3	15
<i>Sceloporus cowlesi</i>	NE	4	6	3	13
<i>Sceloporus cozumelae</i> *	LC	5	7	3	15
<i>Sceloporus cryptus</i> *	LC	5	6	3	14
<i>Sceloporus cupreus</i> *	NE	5	8	3	16
<i>Sceloporus cyanogenys</i> *	NE	6	7	3	16
<i>Sceloporus cyanostictus</i> *	EN	5	8	3	16
<i>Sceloporus druckercolini</i> *	NE	5	6	3	14
<i>Sceloporus dugesii</i> *	LC	5	5	3	13
<i>Sceloporus edwardtaylori</i> *	LC	5	6	3	14
<i>Sceloporus exsul</i> *	CR	6	8	3	17
<i>Sceloporus formosus</i> *	LC	5	7	3	15
<i>Sceloporus gadoviae</i> *	LC	5	3	3	11
<i>Sceloporus goldmani</i> *	EN	5	7	3	15
<i>Sceloporus grammicus</i>	LC	2	4	3	9
<i>Sceloporus grandaevus</i> *	LC	6	7	3	16
<i>Sceloporus halli</i> *	DD	6	8	3	17

<i>Sceloporus heterolepis</i> *	LC	5	6	3	14
<i>Sceloporus horridus</i> *	LC	5	3	3	11
<i>Sceloporus hunsakeri</i> *	LC	5	6	3	14
<i>Sceloporus insignis</i> *	LC	5	8	3	16
<i>Sceloporus internasalis</i>	LC	4	4	3	11
<i>Sceloporus jalapae</i> *	LC	5	5	3	13
<i>Sceloporus jarrovi</i>	LC	2	6	3	11
<i>Sceloporus lemosespinali</i> *	DD	5	8	3	16
<i>Sceloporus licki</i> *	LC	5	5	3	13
<i>Sceloporus lineatulus</i> *	LC	6	8	3	17
<i>Sceloporus lineolateralis</i> *	NE	5	8	3	16
<i>Sceloporus lundelli</i>	LC	4	7	3	14
<i>Sceloporus macdougalli</i> *	LC	5	8	3	16
<i>Sceloporus maculosus</i> *	VU	5	8	3	16
<i>Sceloporus magister</i>	LC	1	5	3	9
<i>Sceloporus marmoratus</i>	NE	2	6	3	11
<i>Sceloporus megalepidurus</i> *	VU	5	6	3	14
<i>Sceloporus melanorhinus</i>	LC	2	4	3	9
<i>Sceloporus merriami</i>	LC	4	6	3	13
<i>Sceloporus minor</i> *	LC	5	6	3	14
<i>Sceloporus mucronatus</i> *	LC	5	5	3	13
<i>Sceloporus nelsoni</i> *	LC	5	5	3	13
<i>Sceloporus oregon</i> *	VU	5	6	3	14
<i>Sceloporus occidentalis</i>	LC	3	6	3	12
<i>Sceloporus ochoterenae</i> *	LC	5	4	3	12
<i>Sceloporus olivaceus</i>	LC	4	6	3	13
<i>Sceloporus orcutti</i>	LC	2	2	3	7
<i>Sceloporus ornatus</i> *	NT	5	8	3	16
<i>Sceloporus palaciosi</i> *	LC	5	7	3	15
<i>Sceloporus parvus</i> *	LC	5	7	3	15
<i>Sceloporus poinsetti</i>	LC	4	5	3	12
<i>Sceloporus prezygus</i>	NE	4	8	3	15
<i>Sceloporus pyrocephalus</i> *	LC	5	4	3	12
<i>Sceloporus salvini</i> *	DD	5	7	3	15
<i>Sceloporus samcolemani</i> *	LC	5	7	3	15
<i>Sceloporus scalaris</i> *	LC	5	4	3	12
<i>Sceloporus serrifer</i>	LC	2	1	3	6
<i>Sceloporus shannonorum</i> *	NE	5	7	3	15
<i>Sceloporus siniferus</i>	LC	2	6	3	11
<i>Sceloporus slevini</i>	LC	2	6	3	11
<i>Sceloporus smaragdinus</i>	LC	4	5	3	12
<i>Sceloporus smithi</i> *	LC	5	7	3	15
<i>Sceloporus spinosus</i> *	LC	5	4	3	12
<i>Sceloporus squamosus</i>	NE	3	5	3	11
<i>Sceloporus stejnegeri</i> *	LC	5	5	3	13
<i>Sceloporus subniger</i> *	NE	5	7	3	15
<i>Sceloporus subpictus</i> *	DD	6	7	3	16
<i>Sceloporus sugillatus</i> *	LC	5	8	3	16
<i>Sceloporus taeniocnemis</i>	LC	4	5	3	12

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<i>Sceloporus tanneri</i> *	DD	6	7	3	16
<i>Sceloporus teapensis</i>	LC	4	6	3	13
<i>Sceloporus torquatus</i> *	LC	5	3	3	11
<i>Sceloporus uniformis</i>	NE	3	7	3	13
<i>Sceloporus utiformis</i> *	LC	5	7	3	15
<i>Sceloporus vandenburgianus</i>	LC	4	7	3	14
<i>Sceloporus variabilis</i>	NE	1	1	3	5
<i>Sceloporus virgatus</i>	LC	4	8	3	15
<i>Sceloporus zosteromus</i> *	LC	5	4	3	12
<i>Uma exsul</i> *	EN	5	8	3	16
<i>Uma notata</i>	NT	4	8	3	15
<i>Uma paraphygas</i> *	NT	6	8	3	17
<i>Uma rufopunctata</i> *	NT	5	8	3	16
<i>Urosaurus auriculatus</i> *	EN	6	7	3	16
<i>Urosaurus bicarinatus</i> *	LC	5	4	3	12
<i>Urosaurus clarionensis</i> *	VU	6	8	3	17
<i>Urosaurus gadovi</i> *	LC	3	6	3	12
<i>Urosaurus graciosus</i>	LC	3	8	3	14
<i>Urosaurus lahtelai</i> *	LC	5	8	3	16
<i>Urosaurus nigricaudus</i>	LC	3	2	3	8
<i>Urosaurus ornatus</i>	LC	2	5	3	10
<i>Uta encantadae</i> *	VU	6	8	3	17
<i>Uta lowei</i> *	VU	6	8	3	17
<i>Uta nolascensis</i> *	LC	6	8	3	17
<i>Uta palmeri</i> *	VU	6	8	3	17
<i>Uta squamata</i> *	LC	6	8	3	17
<i>Uta stansburiana</i>	LC	3	1	3	7
<i>Uta tumidarostra</i> *	VU	6	8	3	17
Family Phyllodactylidae (15 species)					
<i>Phyllodactylus bordai</i> *	LC	5	5	3	13
<i>Phyllodactylus bugastrolepis</i> *	LC	6	8	3	17
<i>Phyllodactylus davisii</i> *	LC	5	8	3	16
<i>Phyllodactylus delcampoi</i> *	LC	5	8	3	16
<i>Phyllodactylus duellmani</i> *	LC	5	8	3	16
<i>Phyllodactylus homolepidurus</i> *	LC	5	7	3	15
<i>Phyllodactylus lanei</i> *	LC	5	7	3	15
<i>Phyllodactylus muralis</i> *	LC	5	6	3	14
<i>Phyllodactylus nocticolus</i>	NE	2	5	3	10
<i>Phyllodactylus partidus</i> *	LC	5	8	3	16
<i>Phyllodactylus paucituberculatus</i> *	DD	6	7	3	16
<i>Phyllodactylus tuberculosus</i>	NE	1	4	3	8
<i>Phyllodactylus unctus</i> *	NT	5	7	3	15
<i>Phyllodactylus xanti</i> *	LC	5	7	3	15
<i>Thecadactylus rapicauda</i>	NE	3	4	3	10
Family Scincidae (23 species)					
<i>Mesoscincus altamirani</i> *	DD	5	6	3	14
<i>Mesoscincus schwartzei</i>	LC	2	6	3	11
<i>Plestiodon bilineatus</i> *	NE	5	5	3	13
<i>Plestiodon brevirostris</i> *	LC	5	3	3	11

<i>Plestiodon callicephalus</i>	LC	2	7	3	12
<i>Plestiodon colimensis</i> *	DD	5	6	3	14
<i>Plestiodon copei</i> *	LC	5	6	3	14
<i>Plestiodon dicei</i> *	NE	5	4	3	12
<i>Plestiodon dugesi</i> *	VU	5	8	3	16
<i>Plestiodon gilberti</i>	LC	3	6	3	12
<i>Plestiodon indubitus</i> *	NE	5	7	3	15
<i>Plestiodon lagunensis</i> *	LC	6	6	3	15
<i>Plestiodon lynxe</i> *	LC	5	2	3	10
<i>Plestiodon multilineatus</i> *	DD	5	8	3	16
<i>Plestiodon multivirgatus</i>	LC	3	8	3	14
<i>Plestiodon nietoi</i> *	NE	6	8	3	17
<i>Plestiodon obsoletus</i>	LC	3	5	3	11
<i>Plestiodon ochoterena</i> *	LC	5	5	3	13
<i>Plestiodon parviauriculatus</i> *	DD	5	7	3	15
<i>Plestiodon parvulus</i> *	DD	5	7	3	15
<i>Plestiodon skiltonianus</i>	LC	3	5	3	11
<i>Plestiodon sumichrasti</i>	NE	4	5	3	12
<i>Plestiodon tetragrammus</i>	LC	4	5	3	12
Family Sphaerodactylidae (4 species)					
<i>Aristelliger georgeensis</i>	NE	3	7	3	13
<i>Gonatodes albogularis</i>	NE	3	5	3	11
<i>Sphaerodactylus continentalis</i>	NE	4	3	3	10
<i>Sphaerodactylus glaucus</i>	NE	4	5	3	12
Family Sphenomorphidae (6 species)					
<i>Scincella gemmingeri</i> *	LC	5	3	3	11
<i>Scincella kikaapoda</i> *	NE ³	6	8	3	17
<i>Scincella lateralis</i>	LC	3	7	3	13
<i>Scincella silvicola</i> *	LC	5	4	3	12
<i>Sphenomorphus assatus</i>	NE	2	2	3	7
<i>Sphenomorphus cherriei</i>	NE	3	2	3	8
Family Teiidae (46 species)					
<i>Aspidoscelis angusticeps</i>	LC	4	6	3	13
<i>Aspidoscelis bacata</i> *	LC	6	8	3	17
<i>Aspidoscelis burti</i>	LC	4	8	3	15
<i>Aspidoscelis calidipes</i> *	LC	5	6	3	14
<i>Aspidoscelis cana</i> *	LC	5	8	3	16
<i>Aspidoscelis carmenensis</i> *	LC	6	8	3	17
<i>Aspidoscelis catalinensis</i> *	VU	6	8	3	17
<i>Aspidoscelis celeripes</i> *	LC	5	7	3	15
<i>Aspidoscelis ceralbensis</i> *	LC	6	8	3	17
<i>Aspidoscelis communis</i> *	LC	5	6	3	14
<i>Aspidoscelis costata</i> *	LC	5	3	3	11
<i>Aspidoscelis cozumela</i> *	LC	5	8	3	16
<i>Aspidoscelis danheimae</i> *	LC	6	7	3	16
<i>Aspidoscelis deppii</i>	LC	1	4	3	8
<i>Aspidoscelis espiritensis</i> *	LC	5	8	3	16
<i>Aspidoscelis exanguis</i>	LC	4	7	3	14
<i>Aspidoscelis franciscensis</i> *	LC	6	8	3	17

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<i>Aspidoscelis gularis</i>	LC	2	4	3	9
<i>Aspidoscelis guttata</i> *	LC	5	4	3	12
<i>Aspidoscelis hyperythra</i>	LC	2	5	3	10
<i>Aspidoscelis inornata</i>	LC	4	7	3	14
<i>Aspidoscelis labialis</i> *	VU	5	7	3	15
<i>Aspidoscelis laredoensis</i>	LC	4	7	3	14
<i>Aspidoscelis lineattissima</i> *	LC	5	6	3	14
<i>Aspidoscelis marmorata</i>	NE	4	7	3	14
<i>Aspidoscelis martyris</i> *	VU	6	8	3	17
<i>Aspidoscelis maslini</i>	LC	4	8	3	15
<i>Aspidoscelis mexicana</i> *	LC	5	6	3	14
<i>Aspidoscelis motaguae</i>	LC	4	5	3	12
<i>Aspidoscelis neomexicana</i>	LC	4	8	3	15
<i>Aspidoscelis opatae</i> *	DD	5	8	3	16
<i>Aspidoscelis parvisocia</i> *	LC	5	7	3	15
<i>Aspidoscelis picta</i> *	LC	6	8	3	17
<i>Aspidoscelis rodecki</i> *	NT	5	8	3	16
<i>Aspidoscelis sackii</i> *	LC	5	6	3	14
<i>Aspidoscelis semptemvittata</i>	LC	3	7	3	13
<i>Aspidoscelis sexlineata</i>	LC	3	8	3	14
<i>Aspidoscelis sonora</i>	LC	4	6	3	13
<i>Aspidoscelis stictogramma</i>	NE	4	7	3	14
<i>Aspidoscelis tessellata</i>	LC	4	7	3	14
<i>Aspidoscelis tigris</i>	LC	3	2	3	8
<i>Aspidoscelis uniparens</i>	LC	4	8	3	15
<i>Aspidoscelis xanthonota</i>	NE	4	7	3	14
<i>Holcosus chaitzami</i>	DD	4	7	3	14
<i>Holcosus festiva</i>	NE	3	5	3	11
<i>Holcosus undulatus</i>	NE	2	2	3	7
Family Xantusiidae (25 species)					
<i>Lepidophyma chicoasense</i> *	DD	6	8	2	16
<i>Lepidophyma cuicateca</i> *	NE ³	6	8	2	16
<i>Lepidophyma dontomasi</i> *	DD	6	6	2	14
<i>Lepidophyma flavimaculatum</i>	NE	1	5	2	8
<i>Lepidophyma gaigeae</i> *	VU	5	6	2	13
<i>Lepidophyma lineri</i> *	DD	5	8	2	15
<i>Lepidophyma lipetzi</i> *	EN	6	8	2	16
<i>Lepidophyma lowei</i> *	DD	6	8	2	16
<i>Lepidophyma micropholis</i> *	VU	5	8	2	15
<i>Lepidophyma occulor</i> *	LC	5	7	2	14
<i>Lepidophyma pajapanense</i> *	LC	5	6	2	13
<i>Lepidophyma radula</i> *	DD	6	5	2	13
<i>Lepidophyma smithii</i>	NE	2	4	2	8
<i>Lepidophyma sylvaticum</i> *	LC	5	4	2	11
<i>Lepidophyma tarascae</i> *	DD	5	7	2	14
<i>Lepidophyma tuxtlae</i> *	DD	5	4	2	11
<i>Lepidophyma zongolica</i> *	NE ³	6	8	2	16
<i>Xantusia bolsonae</i> *	DD	6	8	3	17
<i>Xantusia extorris</i> *	LC	5	7	3	15

<i>Xantusia gilberti</i> *	NE	5	8	3	16
<i>Xantusia henshawi</i>	LC	4	5	3	12
<i>Xantusia jaycolei</i> *	NE	5	8	3	16
<i>Xantusia sanchezi</i> *	LC	5	8	3	16
<i>Xantusia sherbrookei</i> *	NE	5	8	3	16
<i>Xantusia wigginsi</i>	NE	4	7	3	14
Family Xenosauridae (9 species)					
<i>Xenosaurus agrenon</i> *	NE	5	4	3	12
<i>Xenosaurus grandis</i> *	VU	5	1	3	9
<i>Xenosaurus newmanorum</i> *	EN	5	7	3	15
<i>Xenosaurus penai</i> *	LC	6	7	3	16
<i>Xenosaurus phalaroanthereon</i> *	DD	5	8	3	16
<i>Xenosaurus platyceps</i> *	EN	5	6	3	14
<i>Xenosaurus rackhami</i>	NE	4	4	3	11
<i>Xenosaurus rectocollaris</i> *	LC	5	8	3	16
<i>Xenosaurus tzacualtipantecus</i> *	NE	6	8	3	17
Family Boidae (2 species)					
<i>Boa constrictor</i>	NE	3	1	6	10
<i>Charina trivirgata</i>	LC	4	3	3	10
Family Colubridae (136 species)					
<i>Arizona elegans</i>	LC	1	1	3	5
<i>Arizona pacata</i> *	LC	5	5	4	14
<i>Bogertophis rosaliae</i>	LC	2	5	3	10
<i>Bogertophis subocularis</i>	LC	4	7	3	14
<i>Chilomeniscus savagei</i> *	LC	6	7	2	15
<i>Chilomeniscus stramineus</i>	LC	4	2	2	8
<i>Chionactis occipitalis</i>	LC	4	6	2	12
<i>Chionactis palarostris</i>	LC	4	7	2	13
<i>Coluber constrictor</i>	LC	1	6	3	10
<i>Conopsis acuta</i> *	NE	5	7	2	14
<i>Conopsis amphisticha</i> *	NT	5	8	2	15
<i>Conopsis biserialis</i> *	LC	5	6	2	13
<i>Conopsis lineata</i> *	LC	5	6	2	13
<i>Conopsis megalodon</i> *	LC	5	7	2	14
<i>Conopsis nasus</i> *	LC	5	4	2	11
<i>Dendrophidion vinitor</i>	LC	3	7	3	13
<i>Drymarchon melanurus</i>	LC	1	1	4	6
<i>Drymobius chloroticus</i>	LC	1	3	4	8
<i>Drymobius margaritiferus</i>	NE	1	1	4	6
<i>Ficimia hardyi</i> *	EN	5	6	2	13
<i>Ficimia olivacea</i> *	NE	5	2	2	9
<i>Ficimia publia</i>	NE	4	3	2	9
<i>Ficimia ramirezi</i> *	DD	6	8	2	16
<i>Ficimia ruspator</i> *	DD	6	8	2	16
<i>Ficimia streckeri</i>	LC	3	7	2	12
<i>Ficimia variegata</i> *	DD	5	7	2	14
<i>Geagras redimitus</i> *	DD	5	7	2	14
<i>Gyalopion canum</i>	LC	4	3	2	9
<i>Gyalopion quadrangulare</i>	LC	3	6	2	11

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<i>Lampropeltis alterna</i>	LC	4	7	3	14
<i>Lampropeltis californiae</i>	NE ²	3	4	3	10
<i>Lampropeltis catalinensis*</i>	DD	6	8	3	17
<i>Lampropeltis herrerae*</i>	CR	6	8	3	17
<i>Lampropeltis holbrooki</i>	NE ²	3	8	3	14
<i>Lampropeltis knoblochi</i>	NE ²	2	5	3	10
<i>Lampropeltis mexicana*</i>	LC	5	7	3	15
<i>Lampropeltis ruthveni*</i>	NT	5	8	3	16
<i>Lampropeltis splendida</i>	NE ²	4	5	3	12
<i>Lampropeltis triangulum</i>	NE	1	1	5	7
<i>Lampropeltis webbi*</i>	DD	5	8	3	16
<i>Lampropeltis zonata</i>	LC	3	7	5	15
<i>Leptophis ahaetulla</i>	NE	3	3	4	10
<i>Leptophis diplotropis*</i>	LC	5	5	4	14
<i>Leptophis mexicanus</i>	LC	1	1	4	6
<i>Leptophis modestus</i>	VU	3	7	4	14
<i>Liochlorophis vernalis</i>	LC	3	8	3	14
<i>Masticophis anthonyi*</i>	CR	6	8	3	17
<i>Masticophis aurigulus*</i>	LC	5	4	4	13
<i>Masticophis barbouri*</i>	DD	6	8	3	17
<i>Masticophis bilineatus</i>	LC	2	5	4	11
<i>Masticophis flagellum</i>	LC	1	3	4	8
<i>Masticophis fuliginosus</i>	NE	2	3	4	9
<i>Masticophis lateralis</i>	LC	3	3	4	10
<i>Masticophis mentovarius</i>	NE	1	1	4	6
<i>Masticophis schotti</i>	LC	4	5	4	13
<i>Masticophis slevini*</i>	LC	6	8	3	17
<i>Masticophis taeniatus</i>	LC	1	5	4	10
<i>Mastigodryas cliftoni*</i>	NE	5	6	3	14
<i>Mastigodryas melanolomus</i>	LC	1	1	4	6
<i>Opheodrys aestivus</i>	LC	3	7	3	13
<i>Oxybelis aeneus</i>	NE	1	1	3	5
<i>Oxybelis fulgidus</i>	NE	3	2	4	9
<i>Pantherophis bairdi</i>	NE	4	7	4	15
<i>Pantherophis emoryi</i>	LC	3	6	4	13
<i>Phyllorhynchus browni</i>	LC	4	7	2	13
<i>Phyllorhynchus decurtatus</i>	LC	4	5	2	11
<i>Pituophis catenifer</i>	LC	4	1	4	9
<i>Pituophis deppei*</i>	LC	5	5	4	14
<i>Pituophis insulanus*</i>	LC	6	6	4	16
<i>Pituophis lineaticollis</i>	LC	2	2	4	8
<i>Pituophis vertebralis*</i>	LC	5	3	4	12
<i>Pseudelaphe flavirufa</i>	LC	2	4	4	10
<i>Pseudelaphe phaescens*</i>	NE	5	7	4	16
<i>Pseudoficimia frontalis*</i>	LC	5	5	3	13
<i>Pseustes poecilonotus</i>	LC	3	4	3	10
<i>Rhinocheilus antonii*</i>	NE	5	8	3	16
<i>Rhinocheilus etheridgei*</i>	DD	6	7	3	16
<i>Rhinocheilus lecontei</i>	LC	1	3	4	8

<i>Salvadora bairdi</i> *	LC	5	6	4	15
<i>Salvadora deserticola</i>	NE	4	6	4	14
<i>Salvadora grahamiae</i>	LC	4	2	4	10
<i>Salvadora hexalepis</i>	LC	4	2	4	10
<i>Salvadora intermedia</i> *	LC	5	7	4	16
<i>Salvadora lemniscata</i> *	LC	5	6	4	15
<i>Salvadora mexicana</i> *	LC	5	6	4	15
<i>Scaphiodontophis annulatus</i>	NE	1	5	5	11
<i>Senticolis triaspis</i>	NE	2	1	3	6
<i>Sonora aemula</i> *	NT	5	6	5	16
<i>Sonora michoacensis</i> *	LC	5	6	3	14
<i>Sonora mutabilis</i> *	LC	5	6	3	14
<i>Sonora semiannulata</i>	LC	1	1	3	5
<i>Spilotes pullatus</i>	NE	1	1	4	6
<i>Stenorrhina degenhardtii</i>	NE	3	3	3	9
<i>Stenorrhina freminvillii</i>	NE	1	2	4	7
<i>Symphimus leucostomus</i> *	LC	5	6	3	14
<i>Symphimus mayae</i>	LC	4	7	3	14
<i>Sympholis lippiens</i> *	NE	5	6	3	14
<i>Tantilla atriceps</i>	LC	2	7	2	11
<i>Tantilla bocourti</i> *	LC	5	2	2	9
<i>Tantilla briggsi</i> *	DD	6	8	2	16
<i>Tantilla calamarina</i> *	LC	5	5	2	12
<i>Tantilla cascadeae</i> *	DD	6	8	2	16
<i>Tantilla ceboruca</i> *	NE	6	8	2	16
<i>Tantilla coronadoi</i> *	LC	6	7	2	15
<i>Tantilla cuniculator</i>	LC	4	7	2	13
<i>Tantilla deppei</i> *	LC	5	6	2	13
<i>Tantilla flavilineata</i> *	EN	5	7	2	14
<i>Tantilla gracilis</i>	LC	3	8	2	13
<i>Tantilla hobartsmithi</i>	LC	3	6	2	11
<i>Tantilla impensa</i>	LC	3	5	2	10
<i>Tantilla johnsoni</i> *	DD	6	8	2	16
<i>Tantilla moesta</i>	LC	4	7	2	13
<i>Tantilla nigriceps</i>	LC	3	6	2	11
<i>Tantilla oaxacae</i> *	DD	6	7	2	15
<i>Tantilla planiceps</i>	LC	4	3	2	9
<i>Tantilla robusta</i> *	DD	6	8	2	16
<i>Tantilla rubra</i>	LC	2	1	2	5
<i>Tantilla schistosa</i>	NE	3	3	2	8
<i>Tantilla sertula</i> *	DD	6	8	2	16
<i>Tantilla shawi</i> *	EN	5	8	2	15
<i>Tantilla slavensi</i> *	DD	5	7	2	14
<i>Tantilla striata</i> *	DD	5	7	2	14
<i>Tantilla tayrae</i> *	DD	6	7	2	15
<i>Tantilla triseriata</i> *	DD	5	6	2	13
<i>Tantilla vulcani</i>	NE	4	6	2	12
<i>Tantilla wilcoxi</i>	LC	2	6	2	10
<i>Tantilla yaquia</i>	LC	2	6	2	10

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<i>Tantillita brevissima</i>	LC	4	3	2	9
<i>Tantillita canula</i>	LC	4	6	2	12
<i>Tantillita lintoni</i>	LC	4	6	2	12
<i>Trimorphodon biscutatus</i>	NE	2	1	4	7
<i>Trimorphodon lambda</i>	NE	4	5	4	13
<i>Trimorphodon lyrophanes</i>	NE	4	2	4	10
<i>Trimorphodon paucimaculatus*</i>	NE	5	6	4	15
<i>Trimorphodon tau*</i>	LC	5	4	4	13
<i>Trimorphodon wilkinsonii</i>	LC	4	7	4	15
Family Dipsadidae (115 species)					
<i>Adelphicos latifasciatum*</i>	DD	6	7	2	15
<i>Adelphicos newmanorum*</i>	NE	5	5	2	12
<i>Adelphicos nigrilatum*</i>	LC	5	7	2	14
<i>Adelphicos quadrivirgatum</i>	DD	4	4	2	10
<i>Adelphicos sargii</i>	LC	4	6	2	12
<i>Amastridium sapperi</i>	NE	4	4	2	10
<i>Chersodromus liebmanni*</i>	LC	5	5	2	12
<i>Chersodromus rubriventris*</i>	EN	5	7	2	14
<i>Coniophanes alvarezi*</i>	DD	6	8	3	17
<i>Coniophanes bipunctatus</i>	NE	1	5	3	10
<i>Coniophanes fissidens</i>	NE	1	3	3	7
<i>Coniophanes imperialis</i>	LC	2	3	3	8
<i>Coniophanes lateritius*</i>	DD	5	5	3	13
<i>Coniophanes melanocephalus*</i>	DD	5	6	3	14
<i>Coniophanes meridanus*</i>	LC	5	7	3	15
<i>Coniophanes michoacanensis*</i>	NE ³	6	8	3	17
<i>Coniophanes piceivittis</i>	LC	1	3	3	7
<i>Coniophanes quinquevittatus</i>	LC	4	6	3	13
<i>Coniophanes sarae*</i>	DD	5	7	3	16
<i>Coniophanes schmidtii</i>	LC	4	6	3	13
<i>Coniophanes taylori*</i>	NE	5	7	4	16
<i>Cryophis hallbergi*</i>	DD	5	7	2	14
<i>Diadophis punctatus</i>	LC	1	1	2	4
<i>Dipsas brevifacies</i>	LC	4	7	4	15
<i>Dipsas gaigeae*</i>	LC	5	8	4	17
<i>Enulius flavitorques</i>	NE	1	1	3	5
<i>Enulius oligostichus*</i>	DD	5	7	3	15
<i>Geophis anocularis*</i>	LC	6	8	2	16
<i>Geophis bicolor*</i>	DD	5	8	2	15
<i>Geophis blanchardi*</i>	DD	5	8	2	15
<i>Geophis cancellatus</i>	LC	4	6	2	12
<i>Geophis carinosus</i>	LC	2	4	2	8
<i>Geophis chalybeus*</i>	DD	6	7	2	15
<i>Geophis dubius*</i>	LC	5	6	2	13
<i>Geophis duellmani*</i>	LC	5	8	2	15
<i>Geophis dugesi*</i>	LC	5	6	2	13
<i>Geophis immaculatus</i>	LC	4	8	2	14
<i>Geophis incomptus*</i>	DD	6	8	2	16
<i>Geophis isthmicus*</i>	DD	6	8	2	16

<i>Geophis juarezi</i> *	DD	6	8	2	16
<i>Geophis juliai</i> *	VU	5	6	2	13
<i>Geophis laticinctus</i> *	LC	5	4	2	11
<i>Geophis laticollaris</i> *	DD	6	8	2	16
<i>Geophis latifrontalis</i> *	DD	5	7	2	14
<i>Geophis maculiferus</i> *	DD	6	8	2	16
<i>Geophis mutitorques</i> *	LC	5	6	2	13
<i>Geophis nasalis</i>	LC	4	3	2	9
<i>Geophis nigrocinctus</i> *	DD	5	8	2	15
<i>Geophis occabus</i> *	NE ³	6	8	2	16
<i>Geophis omiltemanus</i> *	LC	5	8	2	15
<i>Geophis petersi</i> *	DD	5	8	2	15
<i>Geophis pyburni</i> *	DD	6	8	2	16
<i>Geophis rhodogaster</i>	LC	3	7	2	12
<i>Geophis russatus</i> *	DD	6	8	2	16
<i>Geophis sallei</i> *	DD	6	7	2	15
<i>Geophis semidoliatus</i> *	LC	5	6	2	13
<i>Geophis sieboldi</i> *	DD	5	6	2	13
<i>Geophis tarascae</i> *	DD	5	8	2	15
<i>Heterodon kennerlyi</i>	NE	3	4	4	11
<i>Hypsiglena affinis</i> *	NE	5	7	2	14
<i>Hypsiglena chlorophaea</i>	NE	1	5	2	8
<i>Hypsiglena jani</i>	NE	1	3	2	6
<i>Hypsiglena ochrorhyncha</i>	NE	2	4	2	8
<i>Hypsiglena slevini</i> *	NE	5	4	2	11
<i>Hypsiglena tanzeri</i> *	DD	5	8	2	15
<i>Hypsiglena torquata</i> *	LC	5	1	2	8
<i>Imantodes cenchoa</i>	NE	1	3	2	6
<i>Imantodes gemmistratus</i>	NE	1	3	2	6
<i>Imantodes tenuissimus</i>	NE	4	7	2	13
<i>Leptodeira frenata</i>	LC	4	4	4	12
<i>Leptodeira maculata</i>	LC	2	1	4	7
<i>Leptodeira nigrofasciata</i>	LC	1	3	4	8
<i>Leptodeira punctata</i> *	LC	5	8	4	17
<i>Leptodeira septentrionalis</i>	NE	2	2	4	8
<i>Leptodeira splendida</i> *	LC	5	5	4	14
<i>Leptodeira uribei</i> *	LC	5	8	4	17
<i>Ninia diademata</i>	LC	4	3	2	9
<i>Ninia sebae</i>	NE	1	1	2	5
<i>Pliocercus elapoides</i>	LC	4	1	5	10
<i>Pseudoleptodeira latifasciata</i> *	LC	5	5	4	14
<i>Rhadinaea bogertorum</i> *	DD	6	8	2	16
<i>Rhadinaea cuneata</i> *	DD	6	7	2	15
<i>Rhadinaea decorata</i>	NE	1	6	2	9
<i>Rhadinaea forbesi</i> *	DD	5	8	2	15
<i>Rhadinaea fulvivittis</i> *	VU	5	4	2	11
<i>Rhadinaea gaigeae</i> *	DD	5	5	2	12
<i>Rhadinaea hesperia</i> *	LC	5	3	2	10
<i>Rhadinaea laureata</i> *	LC	5	5	2	12

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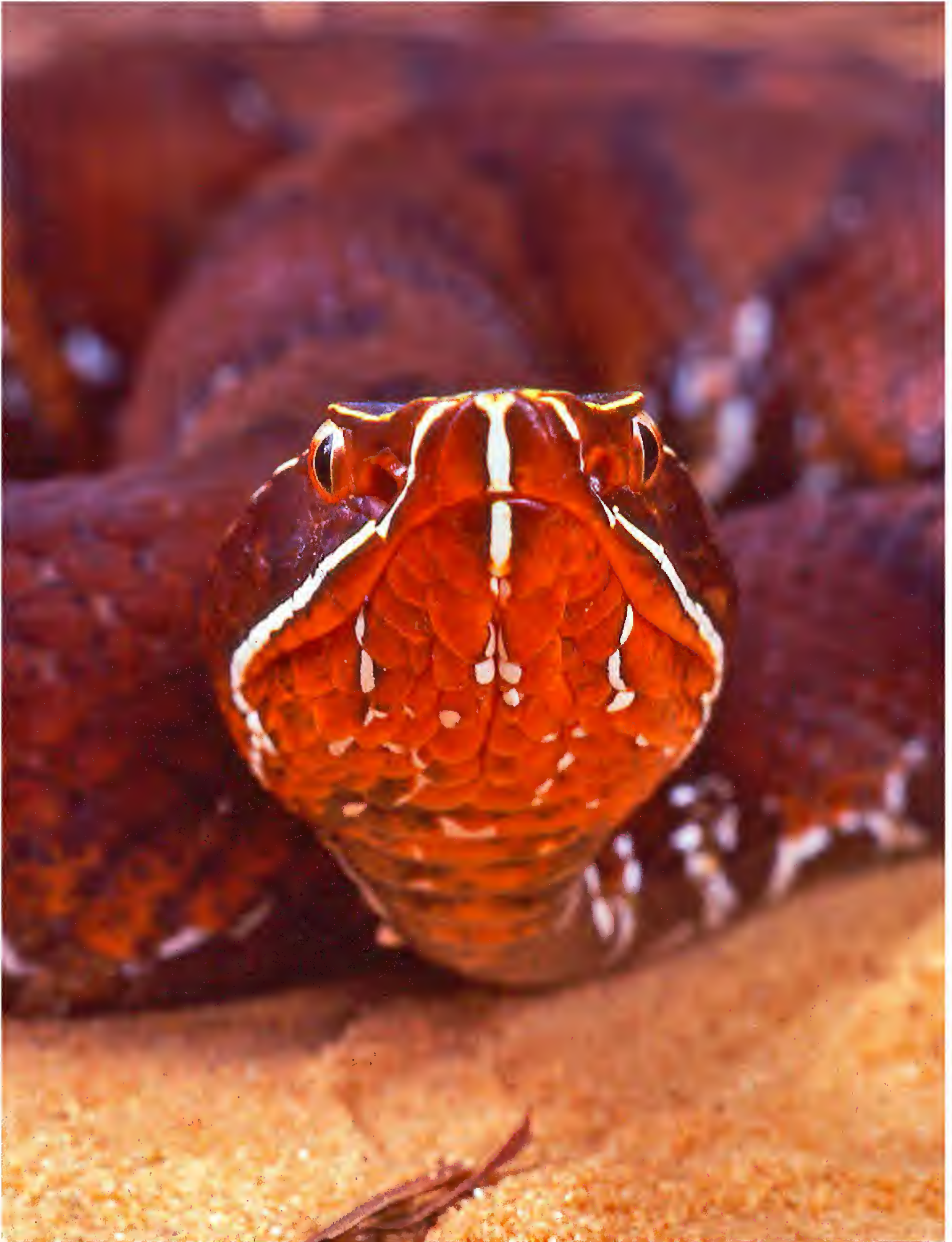
<i>Rhadinaea macdougalli</i> *	DD	5	5	2	12
<i>Rhadinaea marcellae</i> *	EN	5	5	2	12
<i>Rhadinaea montana</i> *	EN	5	7	2	14
<i>Rhadinaea myersi</i> *	DD	5	5	2	12
<i>Rhadinaea omiltemana</i> *	DD	5	8	2	15
<i>Rhadinaea quinquelineata</i> *	DD	5	8	2	15
<i>Rhadinaea taeniata</i> *	LC	5	6	2	13
<i>Rhadinella godmani</i>	NE	3	5	2	10
<i>Rhadinella hannsteini</i>	DD	4	5	2	11
<i>Rhadinella kanalchutchan</i> *	DD	6	8	2	16
<i>Rhadinella kinkelini</i>	LC	4	6	2	12
<i>Rhadinella lachrymans</i>	LC	4	2	2	8
<i>Rhadinella posadasi</i>	NE	4	8	2	14
<i>Rhadinella schistosa</i> *	LC	5	6	2	13
<i>Rhadinophanes monticola</i> *	DD	6	7	2	15
<i>Sibon dimidiatus</i>	LC	1	5	4	10
<i>Sibon linearis</i> *	DD	6	8	2	16
<i>Sibon nebulatus</i>	NE	1	2	2	5
<i>Sibon sanniolus</i>	LC	4	6	2	12
<i>Tantalophis discolor</i> *	VU	5	6	3	14
<i>Tropidodipsas annulifera</i> *	LC	5	4	4	13
<i>Tropidodipsas fasciata</i> *	NE	5	4	4	13
<i>Tropidodipsas fischeri</i>	NE	4	3	4	11
<i>Tropidodipsas philippi</i> *	LC	5	5	4	14
<i>Tropidodipsas repleta</i> *	DD	5	8	4	17
<i>Tropidodipsas sartorii</i>	NE	2	2	5	9
<i>Tropidodipsas zweifeli</i> *	NE	5	7	4	16
Family Elapidae (19 species)					
<i>Laticauda colubrina</i>	LC	—	—	—	—
<i>Micruroides euryxanthus</i>	LC	4	6	5	15
<i>Micrurus bernadi</i> *	LC	5	5	5	15
<i>Micrurus bogerti</i> *	DD	5	7	5	17
<i>Micrurus browni</i>	LC	2	1	5	8
<i>Micrurus diastema</i>	LC	2	1	5	8
<i>Micrurus distans</i> *	LC	5	4	5	14
<i>Micrurus elegans</i>	LC	4	4	5	13
<i>Micrurus ephippifer</i> *	VU	5	5	5	15
<i>Micrurus laticollaris</i> *	LC	5	4	5	14
<i>Micrurus latifasciatus</i>	LC	4	4	5	13
<i>Micrurus limbatus</i> *	LC	5	7	5	17
<i>Micrurus nebularis</i> *	DD	5	8	5	18
<i>Micrurus nigrocinctus</i>	NE	3	3	5	11
<i>Micrurus pachecogili</i> *	DD	6	7	5	18
<i>Micrurus proximans</i> *	LC	5	8	5	18
<i>Micrurus tamaulipensis</i> *	DD	6	8	5	19
<i>Micrurus tener</i>	LC	1	5	5	11
<i>Pelamis platura</i>	LC	—	—	—	—
Family Leptotyphlopidae (8 species)					
<i>Epictia goudotii</i>	NE	1	1	1	3

<i>Rena boettgeri</i> *	NE	5	8	1	14
<i>Rena bressoni</i> *	DD	5	8	1	14
<i>Rena dissecta</i>	LC	4	6	1	11
<i>Rena dulcis</i>	LC	4	8	1	13
<i>Rena humilis</i>	LC	4	3	1	8
<i>Rena maxima</i> *	LC	5	5	1	11
<i>Rena myopica</i> *	LC	5	7	1	13
Family Loxocemidae (1 species)					
<i>Loxocemus bicolor</i>	NE	1	5	4	10
Family Natricidae (33 species)					
<i>Adelophis copei</i> *	VU	5	8	2	15
<i>Adelophis foxi</i> *	DD	6	8	2	16
<i>Nerodia erythrogaster</i>	LC	3	4	4	11
<i>Nerodia rhombifer</i>	LC	1	5	4	10
<i>Storeria dekayi</i>	LC	1	4	2	7
<i>Storeria hidalgoensis</i> *	VU	5	6	2	13
<i>Storeria storerioides</i> *	LC	5	4	2	11
<i>Thamnophis bogerti</i> *	NE	5	7	4	16
<i>Thamnophis chrysocephalus</i> *	LC	5	5	4	14
<i>Thamnophis conanti</i> *	NE	5	8	4	17
<i>Thamnophis cyrtopsis</i>	LC	2	1	4	7
<i>Thamnophis elegans</i>	LC	3	7	4	14
<i>Thamnophis eques</i>	LC	2	2	4	8
<i>Thamnophis errans</i> *	LC	5	7	4	16
<i>Thamnophis exsul</i> *	LC	5	7	4	16
<i>Thamnophis fulvus</i>	LC	4	5	4	13
<i>Thamnophis godmani</i> *	LC	5	5	4	14
<i>Thamnophis hammondi</i>	LC	4	5	4	13
<i>Thamnophis lineri</i> *	NE	5	8	4	17
<i>Thamnophis marcianus</i>	NE	1	5	4	10
<i>Thamnophis melanogaster</i> *	EN	5	6	4	15
<i>Thamnophis mendax</i> *	EN	5	5	4	14
<i>Thamnophis nigronuchalis</i> *	DD	5	3	4	12
<i>Thamnophis postremus</i> *	LC	5	6	4	15
<i>Thamnophis proximus</i>	NE	1	2	4	7
<i>Thamnophis pulchrilatus</i> *	LC	5	6	4	15
<i>Thamnophis rossmanni</i> *	DD	6	8	4	18
<i>Thamnophis rufipunctatus</i>	LC	4	7	4	15
<i>Thamnophis scalaris</i> *	LC	5	5	4	14
<i>Thamnophis scaliger</i> *	VU	5	6	4	15
<i>Thamnophis sirtalis</i>	LC	3	7	4	14
<i>Thamnophis sumichrasti</i> *	LC	5	6	4	15
<i>Thamnophis validus</i> *	LC	5	3	4	12
Family Typhlopidae (2 species)					
<i>Typhlops microstomus</i>	LC	4	7	1	12
<i>Typhlops tenuis</i>	LC	4	6	1	11
Family Ungaliophiidae (2 species)					
<i>Exiliboa placata</i> *	VU	5	8	2	15
<i>Ungaliophis continentalis</i>	NE	3	5	2	10

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Family Viperidae (59 species)					
<i>Agkistrodon bilineatus</i>	NT	1	5	5	11
<i>Agkistrodon contortrix</i>	LC	3	6	5	14
<i>Agkistrodon taylori</i> *	LC	5	7	5	17
<i>Atropoides mexicanus</i>	NE	3	4	5	12
<i>Atropoides nummifer</i> *	LC	5	3	5	13
<i>Atropoides occiduus</i>	NE	4	6	5	15
<i>Atropoides olmec</i>	LC	4	6	5	15
<i>Bothriechis aurifer</i>	VU	3	6	5	14
<i>Bothriechis bicolor</i>	LC	4	5	5	14
<i>Bothriechis rowleyi</i> *	VU	5	6	5	16
<i>Bothriechis schlegelii</i>	NE	3	4	5	12
<i>Bothrops asper</i>	NE	3	4	5	12
<i>Cerrophidion godmani</i>	NE	3	3	5	11
<i>Cerrophidion petlalcalensis</i> *	DD	5	8	5	18
<i>Cerrophidion tzotzilorum</i> *	LC	6	8	5	19
<i>Crotalus angelensis</i> *	LC	6	7	5	18
<i>Crotalus aquilus</i> *	LC	5	6	5	16
<i>Crotalus atrox</i>	LC	1	3	5	9
<i>Crotalus basiliscus</i> *	LC	5	6	5	16
<i>Crotalus catalinensis</i> *	CR	6	8	5	19
<i>Crotalus cerastes</i>	LC	4	7	5	16
<i>Crotalus culminatus</i> *	NE	5	5	5	15
<i>Crotalus enyo</i> *	LC	5	3	5	13
<i>Crotalus ericsmithi</i> *	NE	5	8	5	18
<i>Crotalus estebanensis</i> *	LC	6	8	5	19
<i>Crotalus helleri</i>	NE	4	3	5	12
<i>Crotalus intermedius</i> *	LC	5	5	5	15
<i>Crotalus lannomi</i> *	DD	6	8	5	19
<i>Crotalus lepidus</i>	LC	2	5	5	12
<i>Crotalus lorenzoensis</i> *	LC	6	8	5	19
<i>Crotalus mitchellii</i>	LC	4	3	5	12
<i>Crotalus molossus</i>	LC	2	1	5	8
<i>Crotalus muertensis</i> *	LC	6	8	5	19
<i>Crotalus ornatus</i>	NE	4	4	5	13
<i>Crotalus polystictus</i> *	LC	5	6	5	16
<i>Crotalus pricei</i>	LC	2	7	5	14
<i>Crotalus pusillus</i> *	EN	5	8	5	18
<i>Crotalus ravus</i> *	LC	5	4	5	14
<i>Crotalus ruber</i>	LC	2	2	5	9
<i>Crotalus scutulatus</i>	LC	2	4	5	11
<i>Crotalus simus</i>	NE	3	2	5	10
<i>Crotalus stejnegeri</i> *	VU	5	7	5	17
<i>Crotalus tancitarensis</i> *	DD	6	8	5	19
<i>Crotalus tigris</i>	LC	4	7	5	16
<i>Crotalus totonacus</i> *	NE	5	7	5	17
<i>Crotalus transversus</i> *	LC	5	7	5	17
<i>Crotalus triseriatus</i> *	LC	5	6	5	16
<i>Crotalus tzabcan</i>	NE	4	7	5	16

<i>Crotalus viridis</i>	LC	1	6	5	12
<i>Crotalus willardi</i>	LC	2	6	5	13
<i>Mixcoatlus barbouri</i> *	EN	5	5	5	15
<i>Mixcoatlus browni</i> *	NE	5	7	5	17
<i>Mixcoatlus melanurus</i> *	EN	5	7	5	17
<i>Ophryacus undulatus</i> *	VU	5	5	5	15
<i>Porthidium dunni</i> *	LC	5	6	5	16
<i>Porthidium hespere</i> *	DD	5	8	5	18
<i>Porthidium nasutum</i>	LC	3	6	5	14
<i>Porthidium yucatanicum</i> *	LC	5	7	5	17
<i>Sistrurus catenatus</i>	LC	3	5	5	13
Family Xenodontidae (8 species)					
<i>Clelia scytalina</i>	NE	4	5	4	13
<i>Conophis lineatus</i>	LC	2	3	4	9
<i>Conophis morai</i> *	DD	6	7	4	17
<i>Conophis vittatus</i>	LC	2	5	4	11
<i>Manolepis putnami</i> *	LC	5	5	3	13
<i>Oxyrhopus petolarius</i>	NE	3	6	5	14
<i>Tretanorhinus nigroluteus</i>	NE	3	5	2	10
<i>Xenodon rabdocephalus</i>	NE	3	5	5	13



Cantils (genus *Agkistrodon*) are some of the most feared snakes in Mesoamerica, as their bite and powerful venom have caused numerous human fatalities. Equipped with a large and strikingly-marked head, a stout body, and a nervous attitude that often is mistaken for aggression, these snakes usually are killed on sight. Cantils primarily are found in tropical forests that undergo a prolonged dry season, but occasionally inhabit savannas and areas that flood seasonally after heavy rains. Pictured here is a cantil from Parque Nacional Santa Rosa, in northwestern Costa Rica. *Photo by Louis W. Porras.*

A taxonomic reevaluation and conservation assessment of the common cantil, *Agkistrodon bilineatus* (Squamata: Viperidae): a race against time

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Abstract.—Several lines of evidence suggest that numerous populations of cantils (*Agkistrodon bilineatus*, *A. taylori*), New World pitvipers with a distribution in Mesoamerica, are in rapid decline. We examined the IUCN conservation status for *A. bilineatus*, assessed for the entire range of the species, as well as the Environmental Vulnerability Scores (EVS) provided for certain countries along its distribution. Because of pronounced disparities in these conservation assessments and notable phenotypic differences that coincide with the geographic distribution of certain cantil populations, we conduct a taxonomic reassessment of the common cantil, *Agkistrodon bilineatus* (Günther 1863), to determine if the recognized subspecies of *A. bilineatus* merit specific status. Based on our morphological assessment, biogeographical evidence, and the results of previous DNA-based studies, we elevate the three previously recognized subspecies of *A. bilineatus* to full species (*A. bilineatus*, *A. russeolus*, and *A. howardgloydi*). Given this taxonomic reassessment, we examine the conservation status of the newly elevated taxa, suggest avenues for future studies within this complex of pitvipers, and provide conservation recommendations.

Key words. Character evolution, evolutionary species, Mesoamerica, subspecies concept

Resumen.—Varias líneas de evidencia sugieren que numerosas poblaciones de cantiles (*Agkistrodon bilineatus*, *A. taylori*), víboras de foseta del Nuevo Mundo con una distribución en Mesoamérica, están en rápido declive. Examinamos los resultados sobre el estado de conservación propuestos por la UICN para *A. bilineatus*, que fueron evaluados para la distribución total de la especie, así como los resultados de los Índices de Vulnerabilidad Ambiental (en inglés, Environmental Vulnerability Scores [EVS]) que fueron determinados para esta especie en algunos países a lo largo de su distribución. Por haber disparidades pronunciadas en estas evaluaciones de conservación y diferencias fenotípicas notables que coinciden con la distribución geográfica de ciertas poblaciones de cantiles, en este trabajo realizamos una reevaluación taxonómica del cantil común, *Agkistrodon bilineatus* (Günther 1863), para determinar si las subespecies reconocidas de *A. bilineatus* merecen el estatus de especie. Basado en nuestro análisis morfológico, evidencia biogeográfica y los resultados de anteriores estudios basados en ADN, elevamos las tres subespecies de *A. bilineatus* previamente reconocidas al nivel de especie (*A. bilineatus*, *A. russeolus* y *A. howardgloydi*). Tomando en cuenta esta nueva evaluación taxonómica, examinamos el estado de conservación de los taxones aquí elevados, hacemos sugerencias para estudios futuros dentro de este complejo de víboras de foseta y ofrecemos recomendaciones para su conservación.

Palabras claves. Evolución de caracteres, especies evolutivas, Mesoamérica, concepto de subespecies

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Although the restoration of tropical dry forest is still possible, humanity will not give the globe back to its wild-land denizens, and old-growth tropical dry forest will never again cover large areas.

Janzen 2004: 80.

Introduction

The common cantil (*Agkistrodon bilineatus*) is a polytypic species of North American pitviper with a variably fragmented distribution extending from extreme southwestern Chihuahua and southern Sonora, Mexico, to northwestern Costa Rica, on the Pacific versant, and parts of the Yucatan Peninsula, northern Belize, Guatemala, and extreme western Honduras on the Atlantic versant; it also occurs in Las Islas Marías, an archipelago of four islands located about 100 km west of the state of Nayarit, Mexico (Gloyd and Conant 1990; Campbell and Lamar 2004; Lemos-Espinal and Smith 2007; Babb and Dugan 2008; García-Grajales and Buenorostro-Silva 2011; McCranie 2011). With few exceptions, the dominant vegetation zones occupied by *A. bilineatus* are dry forest, deciduous forest, thorn scrub, and savanna, primarily areas of low relief that have been exploited heavily for irrigated agriculture and where this species mostly has become a rare snake; the elevational range of *A. bilineatus* extends from near sea level to about 1,500 m (Gloyd and Conant 1990; Conant 1992). Along the Pacific coast of Mesoamerica, tropical dry forests were reported as the most endangered of the major tropical ecosystems, with only 0.09% of that region afforded official conservation status (Janzen 1988). A quarter of a century after Janzen's elucidative paper, aside from protected areas, dry forests throughout this region have continued to deteriorate.

In a monographic study of the *Agkistrodon* complex, Gloyd and Conant (1990) provided an extensive review of the cantils, including information on their taxonomy, morphology, distribution, and aspects of their natural history. Based on multiple lines of evidence, Parkinson et al. (2002) conducted a phylogeographic analysis of the cantils and elevated *A. b. taylori* to the rank of full species, emphasizing that the loss of forested areas in the habitat of this species underscored the need for its conservation. More recently, Wilson et al. (2010) compiled an extensive conservation assessment for the entire Mesoamerican herpetofauna, in which numerous authorities provided information on the status of cantils. Although the methodological approaches of these authors varied, it was clear from the outcome that the conservation status of *A. bilineatus* showed dramatic differences when analyzed on a country by country or regional basis, since the reported or estimated IUCN rankings for this species extended the gamut from Least Concern to Critically Endangered (Lavin-Murcio and Lazcano 2010; Sasa et al. 2010). Some authors also

provided Environmental Vulnerability Scores (EVS; a conservation measure developed and used by Wilson and McCranie 1992, 2004, and McCranie and Wilson 2002) for certain countries, and their results were more informative. This measure provides a rough gauge of the theoretical degree that herpetofaunal species are vulnerable to environmental degradation; the scores at the upper end of the scale (ranging from 14 to 20) indicate a greater degree of concern (Wilson et al. 2013), and the EVS for *A. bilineatus* was reported as 15 for Honduras, Nicaragua, and Costa Rica, and as 16 for Belize (Sasa et al. 2010; Stafford et al. 2010; Sunyer and Köhler 2010; Townsend and Wilson 2010).

Based on our field experiences, recent discussions with several colleagues working in regions where cantils occur, and information from the published literature, we echo the statements of several of the aforementioned authorities that in many regions *A. bilineatus* has declined significantly, largely as a result of human activities.

Our principal goal in this paper is to reexamine the conservation status of *A. bilineatus*, inasmuch as the available information suggests that certain populations are declining or imperiled. In conservation biology the threat status of an organism typically is evaluated at the species level, so first we reevaluate the taxonomic status of the three subspecies of *A. bilineatus* (*bilineatus*, *russeolus*, and *howardgloydi*) to determine if any (or all) of them shows sufficient lineage divergence to warrant full species recognition. Accordingly, our conservation assessment develops from our taxonomic conclusions.

Morphological Assessment

Gloyd and Conant (1990) and Campbell and Lamar (2004) provided an extensive amount of biological information on cantils, including excellent drawings of the scalation and pattern of the relevant taxa discussed in this paper, so we relied largely on these sources for our morphological assessment. Unlike previous views (see Gloyd and Conant 1990), the genus *Agkistrodon* now is restricted to the New World (see Molecular Assessment).

As in other pitviper genera, *Agkistrodon* (sensu stricto) is characterized by the presence of a deep facial pit, a vertically elliptical pupil, a large venom gland in the temporal region, and a canaliculated fang on the maxilla followed by a series of smaller replacement fangs. In *Agkistrodon*, however, the scales on the crown generally are large and plate-like, although often they are fragmented or contain partial sutures, and the skull is relatively broad and equipped with short fangs. Other characters include a pronounced canthus rostralis, the presence of a loreal scale in all members except *A. piscivorus*, a robust (or relatively robust) body, and a moderate to long tail. Scale characters such as supralabials, infralabials, and dorsal scale rows at midbody show little variation among the species, although the last of these characters is slightly higher in *A. piscivorus*. The

number of ventral scales is lower in *A. bilineatus* and *A. taylori* than in *A. contortrix* and *A. piscivorus*, and the number of subcaudals is slightly lower in the latter two species. In *Agkistrodon*, some or most of the subcaudal scales are divided, and the terminal spine on the tail tip is turned downward in all the taxa except *A. piscivorus*. Moderate hemipenial differences have been reported among the taxa, but the similarities are more pronounced when comparing *A. contortrix* and *A. piscivorus* to *A. bilineatus* and *A. taylori* (Gloyd and Conant 1990; Malnate 1990). The tail tip of neonates and juveniles of all species of *Agkistrodon* is brightly colored and typically is yellow, white, or pink (Gloyd and Conant 1990). The coloration of the tail tip changes as animals mature, to a faded yellow, green, gray, black, or sometimes to match the color of the dorsum. Young individuals often use their tail to lure prey (e.g., anurans, lizards) by way of vertical undulations and waving, a behavior termed “caudal luring” (reviewed by Strimple 1988, 1992; Carpenter and Gillingham 1990).

1. The cantils

Commonly known as cantils, *A. bilineatus* and *A. taylori* are thick-bodied pitvipers (Serpentes: Viperidae) with a large head and a moderately long and slender tail, and their maximum total lengths are similar. As in the other

species of *Agkistrodon*, the scale characters of cantils only show a moderately low range of variation (Table 1).

A wide range of color pattern variation is evident in *Agkistrodon*, and these characters were used to diagnose the three subspecies of *A. bilineatus* (Burger and Robertson 1951; Gloyd 1972; Conant 1984), as well to elevate *A. taylori* to the rank of full species (Parkinson et al. 2000). The coloration of the head is distinctive, as cantils are adorned with five conspicuous pale stripes, one vertically on the front of the snout and two laterally on each side of the head. The dorsal color pattern consists of crossbands, at least in juveniles, and this character shows a notable degree of geographic and ontogenetic variation. The chin color and ventral coloration also demonstrate considerable geographic variation.

2. Color and pattern characteristics of the ornate cantil

Among the cantils, the color pattern of *A. taylori* is the most vivid (Fig.1). The lower facial stripe is broad and extends to cover the lower edge of the supralabials, the dorsal pattern is composed of pronounced black crossbands separated by gray or pale brown areas that often contain yellowish brown or orange, the chin is patterned with bold markings with wide white or yellow elements, and the venter contains dark gray or black markings



Fig. 1. Adult female *Agkistrodon taylori* from Aldamas, Tamaulipas, Mexico. The ornate cantil often is vividly marked.
Photo by Tim Burkhardt.

Table 1. Maximum total length and selected scale characters in the three subspecies of *Agkistrodon bilineatus* and in *A. taylori*. Min-max values are followed by the mean (in parentheses). Data derived from Gloyd and Conant (1990).

Character	<i>A. b. bilineatus</i>	<i>A. b. russeolus</i>	<i>A. b. howardgloydi</i>	<i>A. taylori</i>
Total length	1,090 mm	1,050 mm*	960 mm	960 mm
Ventrals	127–143 (134.5)	131–141 (136.1)	128–135 (131.1)	127–138 (133.7)
Subcaudals	52–71 (61.6)	46–62 (55.4)	54–61 (58.8)	40–56 (48.3)
Supralabials	5–9 (8.1)	8–9 (8.0)	7–9 (8.0)	7–9 (8.0)
Infralabials	9–13 (10.7)	8–12 (10.8)	9–12 (10.9)	9–12 (10.4)
Dorsal scale rows (midbody)	21–25 (22.9)	23–25 (23.1)	23–25 (23.4)	21–23 (22.9)

*Specimen with an incomplete tail.

arranged in a somewhat checkerboard pattern. In contrast to juveniles, adults exhibit a subdued pattern that contains brighter colors, but older individuals of both sexes tend to become melanistic, and sexual color dimorphism is present in all age classes (Burchfield 1982). The tail tip of young individuals has been reported as sulphur yellow, ivory white, or salmon pink (Burchfield 1982; Gloyd and Conant 1990); the tail tip of most young individuals, however, is sulphur yellow (LWP, GWS, pers. observ.; Fig. 2).



Fig. 2. Neonate female *Agkistrodon taylori* born in captivity from adults collected in the state of Tamaulipas, Mexico. Sexual color pattern dimorphism is evident in all age classes, except in very old individuals that sometimes darken with age. In young males, the rhombs on the dorsum tend to form bands and the interstitial pattern is reduced. *Photo by Breck Bartholomew.*

3. Color and pattern characteristics of the common cantil

In *A. b. bilineatus*, both the upper and lower facial stripes are relatively broad, and the lower stripe is continuous and bordered below by dark pigment along the mouth line. From a frontal view, the vertical stripe along the rostral and mental and the lateral head stripes often meet on the tip of the snout. In adults, the dorsal ground color ranges from very dark brown to black, and if crossbands

are present often they are difficult to distinguish. The dorsal pattern consists of small white spots or streaks. The chin and throat are dark brown or black with a pattern of narrow white lines or markings, and the venter is dark brown or black with pale markings. The coloration of neonates and juveniles is some shade of brown, and consists of brown or chestnut crossbands separated by a paler ground color, with the lateral edges of the crossbands flecked with white. The crossbands gradually fade with maturity, however, as the overall dorsal coloration darkens (Fig. 3). The tail tip of neonates and juveniles has been reported in numerous publications as bright yellow (e.g., Allen 1949; Gloyd and Conant 1990). Sexual color dimorphism has not been reported in any age class.

In *A. b. russeolus*, the upper facial stripe is narrow and sometimes is intermittent posterior to the eye, and the lower stripe is broader and continuous and separated from the commissure by a band of dark pigment. From a frontal view, the vertical stripe along the rostral and mental and the two upper lateral head stripes typically meet on the tip of the snout. The dorsal ground color of adults generally is pale reddish brown, and the pattern consists of broad, deep reddish brown to brown crossbands that are separated dorsally by areas of paler coloration, and often are edged irregularly with white. The crossbands remain apparent, even in older adults. Laterally, the centers of the crossbands are paler and usually contain one or two dark spots. The pattern on the chin and throat often is reduced, with small whitish spots or lines present on a darker background. Approximately the median third of the venter lacks a pattern or contains a few markings. The coloration of a neonate (150 to 175 mm TL) collected near Mérida, Yucatán, was described from life by Howard K. Gloyd (Gloyd and Conant 1990: 83) as showing a velvety appearance, and its pattern consisted of rich chestnut-brown crossbands with rufous brown interspaces, which were edged with blackish brown and interrupted lines of white, “and the tip of the tail gray.” A neonate from Dzibilchaltún, Yucatán, showed a similar coloration except that the banding was edged intermittently only with white, and the tail tip was pale gray with faint white banding (Fig. 4). This individual was maintained in captivity and by the time it had grown to a total



Fig. 3. Young adult *Agkistrodon b. bilineatus* from Apatzingán, Michoacán, Mexico, at an elevation of 330 m. Adult individuals from much of the west coast of Mexico often lose the dorsal banding (see cover of this issue). *Photo by Javier Alvarado.*



Fig. 4. Neonate *Agkistrodon bilineatus russeolus* from Dzibilchaltún, Yucatán, Mexico. Note the pale gray tail tip with faint white banding, and the overall dorsal color pattern. *Photo by Javier Ortiz.*



Fig. 5. Juvenile (ca. 400 mm TL) *Agkistrodon bilineatus russeolus* from Dzibilchaltún, Yucatán, Mexico (same individual as in Fig. 4). With growth, the inner portion of the crossbands turned the same color as the interspaces, and the snake's pattern developed a more fragmented appearance. *Photo by Javier Ortiz.*

length of ca. 400 mm, a marked transformation in color pattern had taken place (Fig. 5). With growth, the inner portion of the crossbands gradually turned the same pale color as the interspaces and the individual's pattern developed a more fragmented appearance; the color of the tail tip also shifted to include darker gray tones (Fig. 5). Henderson (1978) reported the dorsal pattern of a preserved young individual (ca. 380 mm) from Orange Walk Town, Orange Walk District, Belize, as faintly banded, and the tail as grayish-yellow with faint narrow bands. Although Gloyd and Conant (1990: 83) reported the tail

tip of an individual from the same locality as “bright green,” they did not indicate the total length of the snake and an ontogenetic color shift might have occurred. The fragmentation of the banding in *A. b. russeolus* is apparent in the photograph of an adult collected in the outskirts of Consejo, Corozal, Belize (Fig. 6). Sexual color dimorphism has not been reported in juveniles or adults of *A. b. russeolus*.

In *A. b. howardgloydi*, the upper facial stripe is narrow and the posterior part often is absent in adults, and the lower facial stripe is broader and usually divided into two



Fig. 6. Adult *Agkistrodon bilineatus russeolus* from the outskirts of Consejo, Corozal, Belize. Note the fragmented color pattern. Photo by Kevin Zansler, courtesy of Robert A. Thomas.



Fig. 7. Adult *Agkistrodon bilineatus howardgloydi* from Volcán Telica, León, Nicaragua. The color pattern of individuals from this volcanic region often contains black pigment. Photo by Nony Sonati, courtesy of Javier Sunyer.

components that sometimes meet at the suture between the second and third supralabials, and below is bordered by a dark line; the lower edges of the supralabials also are pale in color. From a frontal view, of the five facial stripes

only the top two generally meet on the tip of the snout, but in some individuals all five stripes are connected. The dorsal ground color of adults generally is reddish brown or brown. Adults with black pigment, however, are known from Reserva Natural Volcán Telica in northwestern Nicaragua, with a pattern consisting of darker crossbands that contrast moderately with the dorsal ground color, and along this volcanic area adults sometimes show a dark coloration (J. Sunyer, pers. comm.; Figs. 7, 8). A cantil also was sighted on the eastern shore of Laguna de Xiloá, north of Managua (R. Earley, pers. comm.). The chin and throat are orange yellow, bright orange, or brownish orange with a pattern of a few small white spots, but this coloration terminates abruptly after the first few ventrals. The venter usually is dark reddish brown. The dorsal coloration of juveniles is tan to reddish orange, or reddish, with distinguishable reddish brown crossbands that are edged intermittently with white and/or black, especially as they approach



Fig. 8. Young *Agkistrodon bilineatus howardgloydi* from Volcán Masaya, Masaya, Nicaragua. The color pattern of adults from this area sometimes darkens with age. Photo by Javier Sunyer.



Fig 9. Juvenile (311 mm TL) *Agkistrodon bilineatus howardgloydi* from Parque Nacional Santa Rosa, Guanacaste, Costa Rica. Note the color pattern of the tail tip, which anteriorly to posteriorly turns from very dark to pale gray with corresponding pale gray to white interspaces. Photo by Alejandro Solórzano.

the venter. The tail tip of juveniles is banded with a sequential pattern that ranges from very dark gray anteriorly to paler gray toward the tip, with the interspaces alternating from pale gray to white (Fig. 9). Although Villa (1984: 19) indicated that in Nicaragua “the bright sulphur-yellow tail of the young becomes dark in the adult,” and a photograph of a “juvenile individual” of *A. b. howardgloydi* with what is indicated as a “yellowish tail” appears on the frontispiece, the robust body features of the snake clearly show that it is not a juvenile and its tail is not yellow. We question, therefore, whether Villa might not have assumed that the tail color of *A. b. howardgloydi* would be yellow, as this information long was entrenched in literature regarding *A. b. bilineatus*. With regard to sexual color dimorphism, unlike the other subspecies of *A. bilineatus*, sub-adults and adults of *A. b. howardgloydi* show a moderate degree of sexual color dimorphism; in individuals from Costa Rica, females are distinctly banded and paler in overall coloration, whereas males tend to be darker, with their banding obscured (Figs. 10, 11). Metachrosis, the ability to change color at will or under external stimuli (such as light), was observed in the holotype of *A. b. howardgloydi* (Conant 1984). The coloration of this individual was paler at night (LWP, pers. observ.).



Fig. 10. Adult female *Agkistrodon bilineatus howardgloydi* from Colonia Jobo de la Cruz, Guanacaste, Costa Rica. The color pattern of subadults and adults is paler in females. *Photo by Louis W. Porras.*



Fig. 11. Adult male *A. b. howardgloydi* (holotype) from 0.8 kilometers north of Mirador Cañon del Tigre, Parque Nacional Santa Rosa, Guanacaste, Costa Rica. The color pattern of subadults and adults is darker in males. *Photo by Louis W. Porras.*

Molecular Assessment

Gloyd and Conant (1990) recognized 33 taxa (species and subspecies) in *Agkistrodon* (sensu lato), with a distribution in the Old World and the New World, but subsequent studies using molecular (mtDNA) methods partitioned *Agkistrodon* and demonstrated that the name applies to a monophyletic group of species restricted to the New World (Knight et al. 1992; Kraus et al. 1996; Parkinson et al. 1997, 2002; Parkinson 1999; Castoe and Parkinson 2006; Malhotra et al. 2010). *Agkistrodon* currently is viewed as containing four species, *A. bilineatus*, *A. contortrix*, *A. piscivorus*, and *A. taylori* (Parkinson et al. 2000; Campbell and Lamar 2004), although one subspecies of *A. piscivorus* and two of *A. contortrix* appear to constitute distinct species (Guiher and Burbrink 2008; Douglas et al. 2009).

1. Molecular studies of cantils

Parkinson et al. (2000) provided the first phylogeographic (mtDNA) analysis of cantils, and tested all of the recognized subspecies (*bilineatus*, *howardgloydi*, *russeolus*, and *taylori*). Using maximum parsimony (MP) and maximum likelihood (ML) methods, these authors recovered the clades (*taylori* + (*bilineatus* (*howardgloydi* + *russeolus*))). Furthermore, based on additional lines of evidence (e.g., biogeography, morphology) they recommended the elevation of *taylori* to full species status, whereas the remaining subspecies were thought to be more recently diverged (i.e., having shallower relationships). Using other mtDNA regions (ATPase 8 and 6), and both ML and Bayesian methods of analyses, Douglas et al. (2009) corroborated the results of Knight et al. (1992) and Parkinson et al. (2000) with respect to New World *Agkistrodon*, including the relationships of cantils, although in their study they lacked DNA samples of *A. b. russeolus*.

2. Current views of cantil systematics and taxonomy

Despite efforts by the various aforementioned authorities, a considerable gap in our understanding of the taxonomy and phylogeography of cantils remains. We attribute this outcome largely to insufficient sampling, based on the number of specimens used in their analyses and the number of localities sampled. For example, Knight et al. (1992) included only two samples of cantils (*bilineatus* and *taylori*) and both lacked locality information, although their samples of *taylori* presumably were collected in Tamaulipas, Mexico (A. Knight, pers. comm.). Similarly, Parkinson et al. (2000) reported on only seven samples of cantils, of which two lacked locality data, and their respective samples of *taylori* ($n = 2$) and *howardgloydi* ($n = 2$) each came from the same locality (see Parkinson et al. 2000: table 2). In testing

phylogeographic hypotheses in *Agkistrodon*, Guiher and Burbrink (2008) and Douglas et al. (2009) used extensive sampling of *A. contortrix* and *A. piscivorus*, and both studies used cantils as an outgroup. No new localities for cantils, however, were sampled.

Presently, only limited mtDNA-based sequence data (no nuclear genes have been tested) are available for a handful of specimens of cantils. No definitive molecular information exists for the nominate form, *A. b. bilineatus* (i.e., no study has provided precise locality information) and only one specimen of *A. b. russeolus* (Yucatán, Mexico) has been subjected to a DNA-based inquiry (Parkinson et al. 2000). Given the extensive range of cantils, the limited number of specimens sampled and tested thus far (Mexico: Tamaulipas [no specific locality], Yucatán, [no specific locality]; Costa Rica: Guanacaste Province, Santa Rosa) is inadequate to provide a robust view of their phylogeography. Nonetheless, despite these deficiencies, the available molecular (mtDNA) evidence suggests that the three subspecies of cantils (*A. b. bilineatus*, *A. b. howardgloydi*, and *A. b. russeolus*) can be diagnosed as separate evolutionary entities (per Wiley 1978, 1981).

Character Mapping

Character mapping is a powerful analytical procedure for producing information and gaining insights into character evolution, particularly with respect to origin, direction, and frequency (Brooks and McLennan 1991; Harvey and Pagel 1991; Martins 1996; Fenwick et al. 2011; Maddison and Maddison 2011). Ideally, characters (traits) should be traced onto trees constructed from an explicitly independent data set (Harvey and Pagel 1991; Maddison and Maddison 2011), such as morphological characters mapped onto trees constructed using molecules (e.g., proteins, DNA).

1. Methods

We conducted a character mapping analysis (CMA) of the cantils by using morphological data derived from the literature (Gloyd and Conant 1990; Campbell and Lamar 2004), new information presented in this paper, and unpublished personal data on all species of *Agkistrodon* (sensu stricto) (see Appendix 1). All characters were coded as binary (i.e., 0, 1) or multi-state (e.g., 0, 1, 2). Non-discrete multi-state characters (e.g., color pattern) were ordered from lowest to highest values. Character polarity was established by using two congeners (*A. contortrix* and *A. piscivorus*) as outgroups. The cottonmouth (*A. piscivorus*) is confirmed as the sister group to cantils (Douglas et al. 2009). Ten characters were selected as potential apomorphies (shared-derived traits) and were traced onto a fully resolved tree (six taxa) based on the mtDNA-markers used in Parkinson et al. (2000) and Douglas et al. (2009). Character tracing was performed

separately for each of the 10 traits using outgroup analysis and parsimony procedures in Mesquite (Madison and Madison 2011), and then combining the individual results onto a global tree.

2. Results and discussion

We found 10 morphological characters (scutellation, color pattern traits) selected for the CMA useful in providing broad support for the topology of the molecular tree, as well as robust evidence for the distinctiveness of the taxa, in particular the three subspecies of *A. bilineatus* (Table 2). We thus assign these characters as putative synapomorphies and autapomorphies for *Agkistrodon* (Fig. 12). Although we had a priori knowledge of specific and unique traits used to originally diagnose each of the subspecies, the CMA presents them in a phylogenetic and temporal framework. Accordingly, we show trait evolution with respect to origin, direction, and frequency. For example, we recovered dark dorsal coloration (dark brown or black) as the putative ancestral condition of *Agkistrodon* (Outgroup 1), which is retained in the basal-most cantils (*A. taylori* and *A. b. bilineatus*), but evolved to reddish-brown in the sister clade *A. b. howardgloydi* + *A. b. russeolus*. These types of data can be used in CMA to test explicit hypotheses concerning adaptation, such as seeking correlations of body color to climate, habitat types, and a range of other variables (e.g., Martins 1996).

Allopatry in *A. bilineatus*

In prioritizing a list of vipers for future conservation measures, Greene and Campbell (1992: 423) considered *A. bilineatus* (sensu lato) a taxon of special interest because of its “highly fragmented and biogeographically interesting distribution.” Parkinson et al. (2002) also commented on the relictual nature of the distribution of cantils, and used allopatry as one of their criteria for elevating *A. b. taylori* to species level.

As presently understood, the distribution of *A. b. bilineatus* extends along the Pacific coast of Mexico (including the offshore Las Islas Marías) and northern Central America, from extreme southwestern Chihuahua and southern Sonora to central El Salvador; inland in Mexico, this species has been recorded in northwestern and extreme southeastern Morelos, as well as in the Río Grijalva Valley (Central Depression; Johnson et al. 2010) of Chiapas (Gloyd and Conant 1990; Campbell and Lamar 2004; Castro-Franco and Bustos Zagal 2004; Herrera et al. 2006; Lemos-Espinal and Smith 2007; García-Grajales and Buenorostro-Silva 2011). McCranie (2011) included a photograph of a cantil from extreme western Honduras (Copán, Copán). Based on that photograph, and others provided to us by the collector (R. Garrado, pers. comm.) taken after the animal had reached maturity, the color pattern characteristics of this individual are most similar to those of *A. b. bilineatus* (Fig. 13).

Table 2. Morphological characters used in the character mapping analysis (Fig. 12). See text for details.

Character	State	Designation
Facial striping	absent	A0
	present	A1
Upper facial stripe	absent	B0
	variable	B1
	broad	B2
	narrow	B3
Adult coloration	tan	C0
	black/dark brown	C1
	reddish-brown	C2
Adult dorsal band (same as ground color)	no	D0
	yes	D1
Adult dorsal band color (when present)	brown	E0
	black/dark brown	E1
	multi-colored	E2
	reddish-brown	E3
Throat color	ground-color	F0
	cream/white	F1
	multi-colored	F2
	dark	F3
	brown	F4
	yellow-orange	F5
Juvenile to adult color ontogeny	slight	G0
	pronounced	G1
	moderate	G2
Neonate tail-tip color	yellow	H0
	gray	H1
Neonate tail pattern	slight	I0
	moderate	I1
	pronounced	I2
Sexual color dimorphism	absent	J0
	present	J1

A photograph of what appears to be *A. b. bilineatus*, with a locality of Honduras, also appears in Köhler (2001: fig. 264). The distribution of *A. b. russeolus* primarily extends along the outer part of the Yucatan Peninsula, from west-central Campeche and the northern portion of Yucatán and Quintana Roo on the Gulf side, and in northern Belize on the Caribbean side, although isolated records are available from extreme southeastern Campeche and central Petén, Guatemala (Gloyd and Conant 1990; Campbell 1998; Campbell and Lamar 2004; Köhler 2008). The southernmost population of cantil (*A. b. howardgloydi*)

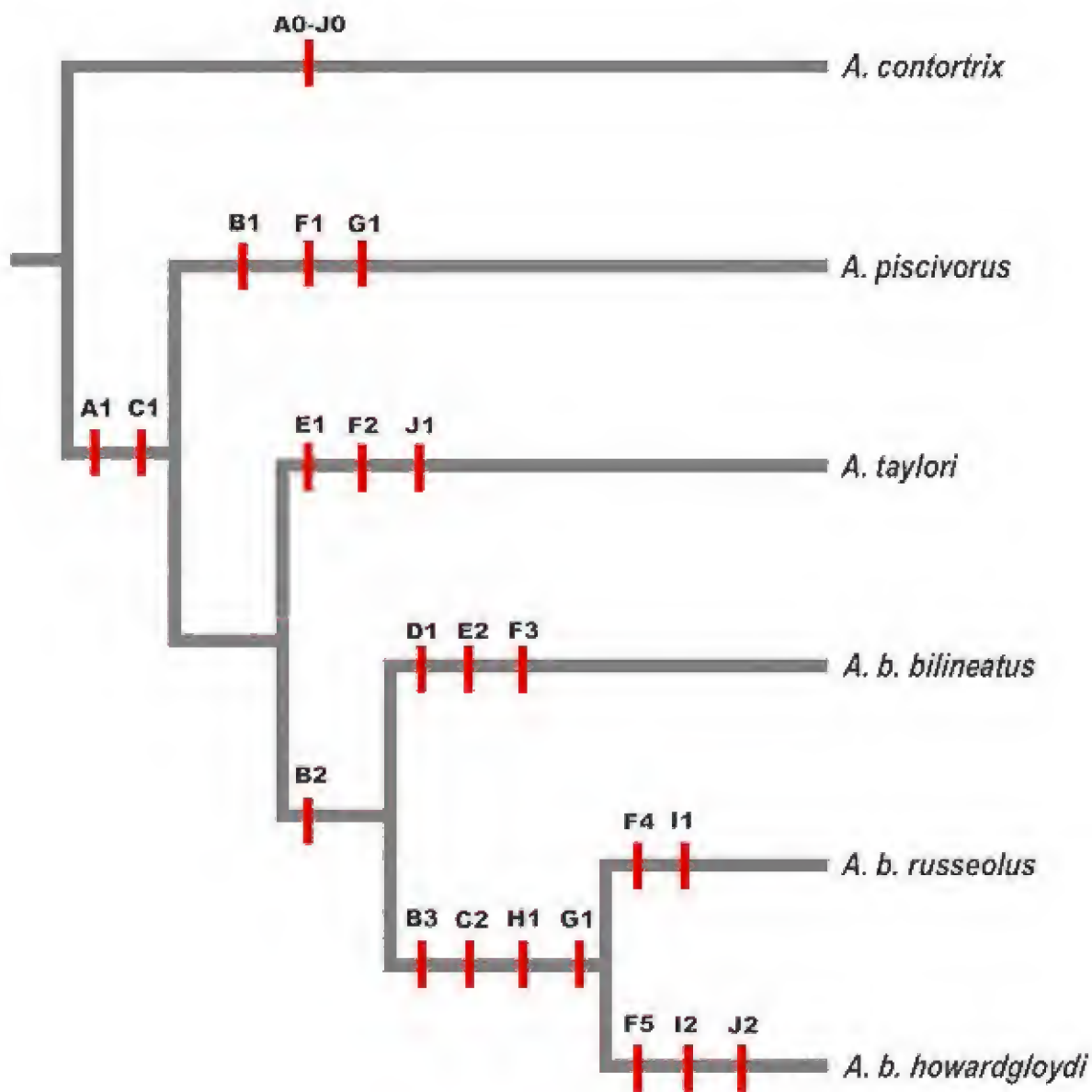


Fig. 12. Character mapping analysis of morphological traits in cantils (*A. b. bilineatus*, *A. b. howardgloydi*, *A. b. russeolus*, and *A. taylori*). Outgroup 1 = *A. piscivorus*; Outgroup 2 = *A. contortrix*. See Table 2 and Appendix 1.



Fig. 13. Young adult *Agkistrodon b. bilineatus* from La Chorchá Lodge, Copán, Honduras at an elevation of 610 m (2,000 feet). Two sightings of this species have occurred at the lodge, in 2003 and 2008. Photo by Robert Gallardo.

occurs along the Pacific coast of Central America from Isla Zacate Grande, in the Golfo de Fonseca, and the adjacent mainland of southern Honduras to the southern limit of Parque Nacional Santa Rosa Park in northwestern Costa Rica (Sasa and Solórzano 1995).

The taxonomic assignment of certain populations of *A. bilineatus*, however, remains problematical. A single individual of cantil was reported from north of Palma Sola, in central coastal Veracruz, an area disjunct from that of all other populations (Blair et al. 1997). Smith and Chiszar (2001) described the specimen as a new subspecies (*A. b. lemosespinali*), but Campbell and Lamar (2004: 266) indicated that this taxon “was diagnosed by several characteristics, all of which are within the normal range of variation for *A. taylori* or might be artifacts in a specimen preserved for more than 30 years.” After examining additional specimens of *A. taylori* from Hidalgo and Veracruz, however, Bryson and Mendoza-Quijano (2007) concluded that the specimen was most closely related to, if not conspecific with, *A. b. bilineatus*, but that it also differed from all of the subspecies of *A. bilineatus* in its tail length to total length ratio. Bryson and Mendoza-Quijano (2007) further commented that the presence of *A. bilineatus* in coastal Veracruz lends corroboration to the transcontinental dispersal hypothesis presented by Parkinson et al. (2002).

Another isolated population is known from the Atlantic versant of central Guatemala, from the Río Chixoy (Negro) Valley (Campbell and Lamar 1989). Gloyd and Conant (1990) commented that two specimens from this area show similarities in color pattern to each of the three populations of *A. bilineatus* occurring in Central America. Until additional specimens and/or molecular data are available, however, the taxonomic status of this allopatric population is uncertain and remains for future investigation. Similarly,

the population in the Central Depression of Chiapas, Mexico, and adjacent western Guatemala merits further examination.

In summary, the distribution of *A. bilineatus* is disjunct or fragmented throughout its extensive range, and thus we contend that three identifiable areas of its distribution are biogeographically distinct. Except for certain issues that remain unresolved (see Discussion), these regions of allopatry constitute the ranges of *A. b. bilineatus*, *A. b. russeolus*, and *A. b. howardgloydi* (see Distribution Map [Fig. 14] below).

Our Taxonomic Position

Six decades ago, Wilson and Brown (1953) discussed the recognition of subspecies in biology and were among the first to advocate, with compelling academic vigor, to halt the use of trinomials in taxonomy. Since their provocative paper was published, a flurry of literally hundreds of papers on the utility of infraspecific categories has appeared, of which many applauded the insights of Wilson and Brown (1953) and supported abandoning the recognition of subspecies (e.g., Edwards 1954; Donoghue 1985; Ball and Avise 1992; Douglas et al. 2002; Zink 2004), whereas others criticized their views as biologically short sighted (e.g., Sibley 1954; Durrant 1955; Crusz 1986; Mallet 1995). Even with the application of an integrative taxonomic approach (reviewed by Padial and de la Riva 2010), a unified concept of species and consequences for solving the problems of species delimitation (see de Queiroz 2007), or a general species concept approach as presented by Hausdorf (2011), no perfect solutions are available to resolve all of the conflicting viewpoints. Nevertheless, Padial and de la Riva (2010: 748) argued that on the basis of the evolutionary species concept, “the point of separation from [a] sister lineage is what marks the origin of a species...and neither subspecies nor ‘subspeciation’ are logically needed.” Importantly, this statement implies that there are no “stages of speciation,” i.e., subspecies are not “on their way” to becoming species. We also share the opinion of Johnson et al. (2010: 327), who asserted that the species level is “the lowest evolutionary lineage segment that should be used in a formal phylogenetically based taxonomy...In this modern taxonomic hierarchy, all taxa except for subspecies are hypothesized to consist of separate evolutionary lineages, and thus subspecies should not be recognized as a formal taxonomic unit.” Moreover, today new subspecies rarely are described in most major zoological journals, although many authors retain already-recognized subspecies as a provisional measure (e.g., Oatley et al. 2011). Here, we adopt the position on subspecies outlined by Wilson and Brown (1953) and subsequently supported by hundreds of biologists (reviewed by Burbrink et al. 2000; Douglas et al. 2002; Johnson et al. 2010).

Taxonomic Conclusions

The taxonomic overview and analysis we provide for the three putative subspecies of the common cantil (*A. b. bilineatus*, *A. b. russeolus*, and *A. b. howardgloydi*) substantiates that sufficient morphological (color and pattern), molecular (mtDNA), and ecological (biogeographical) data are available to consider these taxa as separate and diagnosable entities with their own evolutionary trajectories (see Wiley 1981; Wiley and Mayden 2000; Douglas et al. 2002). As we view it necessary to adopt and identify a species concept (Padial and de la Riva 2010), we used the evolutionary species concept (ESC) introduced by Wiley (1978, 1981). We agree with others that the ESC is preferred among the species hypotheses, since it best accommodates both morphological and molecular information (Wiley and Mayden 2000; Schwentner et al. 2011).

Accordingly, we elevate the three subspecies of *A. bilineatus* to full species and suggest the following common names: *Agkistrodon bilineatus* (common cantil), *A. russeolus* (Yucatecan cantil), and *A. howardgloydi* (southern cantil). We indicate the reported localities for all the cantils, including *A. taylori*, in a distribution map (Fig. 14).

Conservation Assessment

Up to 2006, the conservation status of *Agkistrodon bilineatus* (sensu lato) was judged by the IUCN as Least Concern, but in 2007, presumably as a result of the reptile assessment undertaken in September 2005, in Jalisco, Mexico, the status was changed to Near Threatened (IUCN Red List website; accessed 20 February 2013). Given that we elevated each of the three subspecies of *A. bilineatus* to full species, we will assess their conservation status individually.

1. Application of the IUCN rankings

The IUCN categories for assigning conservation status are the most widely used scheme for attempting to assess the degree of extinction risk for taxa at the species level (www.iucnredlist.org). The criteria used for this assessment are stipulated in the Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1; August 2010). Those with the greatest application to Mesoamerican reptile populations involve the extent of occurrence (i.e., geographic range), and at least two criteria regarding the degree of range fragmentation, the degree of decline in one of a number of distributional or populational characteristics, or the degree of fluctuations in any of these characteristics. The extent of occurrence is related to the threat categories as follows: Critically Endangered (< 100 km²); Endangered (< 5,000 km²); and Vulnerable (< 20,000 km²).



Fig. 14. Distribution map of the reported localities for cantils, including some indicated in this paper. Green is used to designate localities from where we regard the systematic status of cantils as undetermined.

Under our new taxonomic arrangement, the distribution of *A. bilineatus* (sensu stricto) is extended to include extreme western Honduras, in the vicinity of the city of Copán on the Caribbean versant (McCrane 2011). Thus, its extent of distribution well exceeds the 20,000 km² that forms the upper cutoff for a Vulnerable species; it also is greater than the 250,000 km² indicated by García (2006) as the combined extent of the six dry forest ecoregions in Pacific coastal Mexico, in addition to its range in Central America. Given its approximate geographic distribution, it clearly lies outside of the upper size limits for any of the IUCN threat categories. In addition, this species does not appear to qualify as Near Threatened, given that “the taxon should be close to qualifying for the Vulnerable category. The estimates of population size or habitat should be close to the Vulnerable thresholds, especially when there is a high degree of uncertainty” (IUCN 2010: 63). If, however, *A. bilineatus* cannot be judged as Near Threatened, only three other categories are available, viz., Extinct, Least Concern, and Data Deficient. The species is not Extinct, or as we maintain in this paper not of Least Concern, and also does not classify as Data Deficient because enough information was

available for it to be judged as Near Threatened (Lee and Hammerson 2007). In light of this information, we contend that *A. bilineatus* (sensu stricto) should be judged as Near Threatened. A broad-scale assessment of this snake’s conservation status throughout its distribution is extremely critical, however, since much of its area of occurrence has been subjected to considerable human population growth.

In Mexico, *A. bilineatus* primarily occurs in the coastal portion of nine states from Sonora to Chiapas, as well as in Morelos. According to information obtained from Wikipedia (www.wikipedia.org), here and elsewhere in this section, these 10 states have a combined human population of 33,432,935 (29.0% of the 2012 population of Mexico). With a growth rate of 1.4% for the country (Population Reference Bureau 2010) and an estimated doubling time of 50 years, if these growth rates remain comparable the population of these states will reach 66,865,870 by the year 2063. Although these figures and projections apply to an area greater than the total range of *A. bilineatus* in Mexico, they signal grave concern for the survival of these populations.

The prospects for the future of *A. bilineatus* in Guatemala and El Salvador are equally as disturbing. Guatemala is the most rapidly growing country in Central America, with a human population 13,824,463 in 2011, a growth rate of 2.8%, and an estimated doubling time of 25 years, and El Salvador already has become the most densely populated region in Mesoamerica. These statistics, therefore, portend a gloomy picture for the flora and fauna of these countries.

Consequently, in light of these data, we consider *A. bilineatus* as Near Threatened, while conceding that future population analyses might demonstrate a threatened status.

The distribution of *A. russeolus* is much greater than 100 km² (the upper cutoff point for a Critically Endangered species), but significantly less than 5,000 km² (the upper cutoff point for an Endangered species). Thus, based on the extent of occurrence, *A. russeolus* should be judged as an Endangered species. According to the maps in Gloyd and Conant (1990), Lee (1996), Campbell and Lamar (2004), and Köhler (2008), *A. russeolus* is known from up to twelve localities, depending on the level of discrimination. Most of these localities are from the state of Yucatán, from the vicinity of Mérida, Motul, and Pisté. Given this number of locations ($n = 12$), *A. russeolus* should be assessed as Vulnerable, since the criterion for this category is ≤ 10 , as opposed to Endangered, which is ≤ 5 . These records are historical, however, with some dating prior to 1895 (sensu Gloyd and Conant 1990), and to our knowledge no modern survey has been undertaken to ascertain the viability of cantil populations in these regions.

The human population of the three Mexican states occupying the Yucatan Peninsula, Campeche, Yucatán, and Quintana Roo, is over 4,000,000 (Population Reference Bureau 2010). Most of the historical records for *A. russeolus* are from the state of Yucatán, the most populous of the three with a current population of about 2,000,000. Specimens assigned to *A. russeolus* have been reported from seasonally dry forest in northern Belize, from Corozal and northern Belize Districts (Stafford and Meyer 2000), and the savanna area of central Petén, Guatemala (Campbell 1998).

Lee and Hammerson (2007) indicated that the major factor affecting the long-term viability of populations of *A. bilineatus* (sensu lato) is “the extreme pressure from persecution leading to population reductions of close to 30% over the last 15 to 30 years...” According to J. Lee (pers. comm.), this evaluation cannot be applied precisely to *A. russeolus*, but would point to a Critically Endangered status based on criterion C1, i.e., an estimate of continuing decline of at least 25% in 3 years or one generation (IUCN 2010). Lee (1996: 399) commented that, “*Agkistrodon bilineatus* [sensu lato] is a dangerously venomous snake that is widely feared by the native people of Yucatán. It is believed to be capable of

prodigious jumps and to deliver venom both through its bite and with its tail, which is thought to act as a stinger...” Lee (1996: 416) also discussed the historical and the modern attitude toward snakes in general and *A. russeolus* (as *A. bilineatus*) in particular, in his chapter on ethnoherpetology in the Yucatan Peninsula, indicating that the cantil or uolpoch (the Mayan name) “is considered by many contemporary Maya to be the most dangerous of all Yucatecan snakes.” This attitude translates into this snake being killed on sight (J. Lee, pers. comm.). Consequently, based on the available information on the conservation status of *A. russeolus*, we consider this species as Endangered. A conservation assessment needs to be undertaken, however, to determine if this categorization is appropriate, or whether the category of Critically Endangered would be more applicable.

Agkistrodon howardgloydi is distributed in apparently fragmented populations that extend from Isla Zacate Grande in the Golfo de Fonseca and the adjacent mainland of southern Honduras (McCranie 2011), western Nicaragua in the area west of Río Tipitapa and the northwestern shore of Lago de Nicaragua (Köhler 1999, 2001), and in extreme northwestern Costa Rica from Bahía Salinas, near the Nicaraguan border, to the sectors of Santa Rosa and Guanacaste, both in Área de Conservación Guanacaste (Conant 1984; Solórzano 2004). Gloyd and Conant (1990: 92) discussed additional Nicaraguan localities that would extend the distribution northeastward into the southwestern tip of Departamento Jinotega, but this record is one of several supplied to the authors by Jaime Villa. Unfortunately, these specimens were in Villa’s “personal collection that was destroyed during the earthquake and fire that devastated Managua beginning on December 23, 1972.” Like Köhler (1999, 2001), we discounted these records until museum specimens are available from those areas to provide verification. The extent of this species’ range, therefore, apparently is greater than 100 km² but less than 5,000 km², so on the basis of its extent of occurrence it would be assessed as Endangered. With respect to the number of localities, three have been reported for Honduras, including one based on a photograph in Köhler et al. (2006), five from Nicaragua (Köhler 2001; a sight record in this paper), and five from Costa Rica (Conant 1984; Savage 2002); most of these localities in Costa Rica, however, fall within Parque Nacional Santa Rosa, so their total number could be considered as few as two. Thus the total number of localities would range from 10 to 13, which technically would place this species in the Near Threatened category, but again historical records (Nicaragua) date back to 1871 (Gloyd and Conant 1990). As a consequence, this species would appear to fall in the Vulnerable category. Furthermore, given the localized distribution of *A. howardgloydi* in Costa Rica, it is noteworthy that this species was not reported from the country until 1970 (Bolaños and Montero 1970).

Agkistrodon howardgloydi occurs in disjunct populations in Honduras, Nicaragua, and Costa Rica, in lowland dry forest—the most endangered of the major forest types in Mesoamerica (Janzen 2004). In Honduras, nearly all of this forest has been removed from the Pacific coastal plain. A telling feature in McCranie (2011: table 22) is that of the protected areas in Honduras currently supporting “some good forest,” not one contains lowland dry forest. Based on figures from 2001, the departments of Choluteca and Valle each rank among the top five in human population density in the country. As noted by Solórzano et al. (1999), M. Sasa was unsuccessful in finding this species at several localities in the Golfo de Fonseca and indicated that most of the locals were unaware of its existence. These disturbing reports and observations suggest that low population densities (or local extirpation) might be the trend. Similarly, McCranie (2011) noted that professional collectors in Choluteca failed to identify this species from photographs. Also, three of us (LWP, LDW, GWS) have been unsuccessful in finding this species on Isla Zacate Grande, in the Golfo de Fonseca, and on the adjacent mainland.

According to Sunyer and Köhler (2010: 494), similar population trends prevail in Nicaragua, since *A. howardgloydi* (as *A. bilineatus*) is restricted to lowland dry forest in the western part of the country, and “this formation has undergone severe human alteration.” Although *A. howardgloydi* apparently occurs in at least three protected areas, 75% of the protected areas in Nicaragua “contain less than 50% of their original forest cover...” (Sunyer and Köhler 2010: 505). The five known localities for this species in Nicaragua (Köhler 2001; this paper) all are from the most heavily populated region in the country, an area that likely harbored more extensive populations of this species in the past.

In Costa Rica, the conservation of *A. howardgloydi* is more promising, as most of the restricted range of this species is located within the Área de Conservación Guanacaste. In this region, populations have been reported as “relatively stable and protected” (Solórzano 2004: 622). At Parque Nacional Santa Rosa, for example, 21 individuals were obtained for study from 1993 to 1996 (Solórzano et al. 1999). Nonetheless, Sasa et al. (2010: table 8) indicated that although the distribution of this species has been reduced by slightly more than 20% from a potential distribution of 6,883 km², only a little more than 13% of that reduced distribution (5,465 km²) is located within reserves. Like other venomous snakes, we can assume that this species is killed on sight in the 87% of the reduced range outside of protected areas. An important factor in this species’ favor is that the human population growth rate of Costa Rica (1.2%) is the lowest in Central America, and that Guanacaste Province, which encompasses the snake’s entire range in Costa Rica, is the most sparsely populated of all the provinces.

Although the population of *A. howardgloydi* in protected areas of Costa Rica apparently remains stable,

throughout most of the range populations have been extirpated (or are nearing extirpation). Thus, in light of the conservation prospects for *A. howardgloydi*, we consider this species as Endangered with the understanding that a range-wide conservation assessment is required, especially in Honduras and Nicaragua.

2. Application of the EVS

The conservation status algorithm known as the Environmental Vulnerability Score (EVS) was developed by Wilson and McCranie (1992) for use with amphibians in Honduras and subsequently applied to both amphibians and reptiles in this country (Wilson and McCranie 2004). The EVS was utilized in a broader fashion in most of the chapters dealing with Central American countries in Wilson et al. (2010), and in all cases used at the country level. As noted in the Introduction of this paper, the EVS for *A. bilineatus* (sensu lato) in four Central American countries fell within the upper end of the vulnerability scale (Wilson and McCranie 2004).

Originally, the EVS algorithm was constructed for use strictly within Honduras, and thus had limited utility outside of that country. For example, the scale used for Honduras was as follows:

- 1 = widespread in and outside of Honduras
- 2 = distribution peripheral to Honduras, but widespread elsewhere
- 3 = distribution restricted to Nuclear Middle America (exclusive of Honduran endemics)
- 4 = distribution restricted to Honduras
- 5 = known only from the vicinity of the type locality

In its original form, four of the five levels of this scale could not be used outside of Honduras. For the EVS to have a broader application, therefore, it required reconstruction and this recently was accomplished for Belize (Stafford et al. 2010), Nicaragua (Sunyer and Köhler 2010), and Costa Rica (Sasa et al. 2010).

In order to use the EVS measure independent of country divisions, it requires additional reconstruction, as follows:

- 1 = distribution extending from North America (United States and Canada) to South America
- 2 = distribution extending from North America to Mesoamerica or from Mesoamerica to South America
- 3 = distribution restricted to Mesoamerica
- 4 = distribution restricted to a single physiographic region within Mesoamerica
- 5 = known only from the vicinity of the type locality

The other components of the gauge require only minimal reconstruction. The ecological distribution component can be revised as follows:

- 1 = occurs in eight or more formations
- 2 = occurs in seven formations
- 3 = occurs in six formations
- 4 = occurs in five formations

- 5 = occurs in four formations
- 6 = occurs in three formations
- 7 = occurs in two formations
- 8 = occurs in one formation

The only modification of this component is that the first level was changed from “occurs in eight formations” to “occurs in eight or more formations” (see Wilson and McCranie 2004). This change appears acceptable, since very few species in Mesoamerica occupy more than eight formations (see Wilson and Johnson 2010: table 16).

The component for the degree of human persecution in reptiles (a different measure was used for amphibians) is the same as used by Wilson and McCranie (2004), as follows:

- 1 = fossorial, usually escape human notice
- 2 = semifossorial, or nocturnal arboreal or aquatic, non-venomous and usually non-mimicking, sometimes escape human notice
- 3 = terrestrial and/or arboreal or aquatic, generally ignored by humans
- 4 = terrestrial and/or arboreal or aquatic, thought to be harmful, might be killed on sight
- 5 = venomous species or mimics thereof, killed on sight
- 6 = commercially or non-commercially exploited for hides and/or meat and/or eggs

Based on these changes to the EVS, the calculated scores for the three species of cantils are as follows:

- A. bilineatus*: $3 + 5 + 5 = 13$
- A. russeolus*: $4 + 6 + 5 = 15$
- A. howardgloydi*: $4 + 8 + 5 = 17$

Consequently, the value for *A. bilineatus* falls at the upper end of the medium vulnerability category, and the values for *A. russeolus* and *A. howardgloydi* fall into the high vulnerability category.

In summary, the IUCN categorizations and EVS values for these three taxa are as follows: *A. bilineatus* (Near Threatened and 13); *A. russeolus* (Endangered and 15); and *A. howardgloydi* (Endangered and 17). Interestingly, the IUCN has assessed *A. taylori* as a species of Least Concern (Lavin et al. 2007), whereas the EVS for this taxon is reported as 17 (Wilson et al. 2013).

Discussion

We provided a substantive review of the taxonomy and conservation status of the common cantil (*A. bilineatus*, sensu lato). Our taxonomic assessment led us to elevate the three subspecies of *A. bilineatus* to full species (*A. bilineatus*, *A. howardgloydi*, and *A. russeolus*), based on multiple lines of evidence. Nonetheless, we are not confident that this arrangement necessarily captures the full diversity of this widely distributed group of pitvipers.

Accordingly, we identified several regions where additional sampling must be accomplished, but overall we recommend a thorough phylogeographic analysis employing morphological analyses and the use of both mtDNA and nuclear (e.g., introns, microsatellites) markers. Owing largely to the isolation of certain populations, we suspect that additional species will be discovered within this complex.

The population of *A. bilineatus* in southern Sonora and adjacent southwestern Chihuahua, Mexico, for example, occurs in a distinctive habitat (“Sonoran-Sinaloan transition subtropical dry forest” according to the WWF [see García 2006]), the color pattern of adults differs somewhat from that of typical *A. bilineatus* (Fig. 15), and a moderate hiatus exists from the closest-known population to the south (49 miles [78.8 kilometers] south of Culiacán, Sinaloa, Mexico; Hardy and McDiarmid 1969; Campbell and Lamar 2004).

Another example is the insular population on Las Islas Marías. On this offshore group of islands, two specimens collected in 1881 were reported from the “Tres Marías” (without naming a specific island), and one specimen from Isla María Grande was collected in 1897 (Boulenger 1896; Stejneger 1899; see Zweifel 1960). Interestingly, Gloyd and Conant (1990) indicated that the cantil with the greatest total length is among these specimens, as well as the *A. b. bilineatus* (sensu lato) with the lowest number of subcaudals. Gloyd and Conant (1990), however, considered this latter specimen as aberrant, but commented (p. 69) that “Whether other aberrant specimens occurred on the islands probably will never be known, inasmuch as the species may now have been extirpated from the archipelago.” Casas-Andreu (1992) indicated the presence of *A. bilineatus* on other islands of the Las Islas Marías chain (on Isla San Juanito and Isla María Magdalena). According to G. Casas-Andreu (pers. comm.), however, these records were not based on new material, as no cantils were encountered during his survey in 1986, but rather they were obtained from the literature. Inasmuch as no literature citations or museum numbers for these specimens appear in Casas-Andreu (1992), our knowledge of the distribution of *A. bilineatus* on Las Islas Marías remains sketchy. Although some areas of “good habitat” were present in the archipelago in 1986 (G. Casas-Andreu, pers. comm.), habitat destruction, a growing human population (including a large penal colony), the presence of agricultural camps and domestic animals, the outright killing of fauna, and the introduction of rats and feral cats all had become a significant problem (Casas-Andreu 1992). In 2000, the archipelago and its surrounding waters were declared an international protected area (Reserva de la Biósfera Islas Marías). In spite of the lack of information on *A. bilineatus* from these islands, the only reptiles protected under the Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT) are *Crocodylus acutus* (special protection), *Iguana iguana* (special protection), *Ctenosaura*



Fig. 15. Adult *Agkistrodon bilineatus* found by Larry Jones and Thomas Skinner in August of 2005, ca. 12 km NW of Alamos, Sonora, Mexico. This individual later was released. Photo by James C. Rorabaugh.



Fig. 16. Young cantil from Aldea La Laguna, Nentón, Huehuetenango, Guatemala. The specific allocation of this population remains uncertain (see Fig. 14). Photo by Manuel Acevedo.

pectinata (threatened), and *Eretmochelys imbricata* (in danger of extinction) (Anonymous 2007). A determination of the actual distribution and population status of *A. bilineatus* on Las Islas Marías, therefore, is a conservation priority.

The taxonomic status of *A. b. lemosespinali*, which tentatively was assigned to *A. b. bilineatus* by Bryson and Mendoza-Quijano (2007), remains unresolved. Known from a single specimen from Palma Sola, in coastal central Veracruz, Mexico, this area was noted

by Smith and Chizar (2001: 133) as highly agricultural and located next to a nuclear power plant regarded by “many local residents and environmentalists in general as having contaminated the surrounding area with radioactivity.” These authors further indicated that if “*A. b. lemosespinali* ever occurred in that area, it is likely now to be extinct, or it likely would have been found [again] long ago.”

Other disjunct populations of cantils merit a closer examination at both morphological and molecular levels, such as those from the Central Depression of Chiapas and the headwaters of the Río Grijalva that extend into northwestern Guatemala (Fig. 16), the Río Chixoy and Motagua valleys of Guatemala, as well as isolated populations of *A. russeolus* (Gloyd and Conant 1990; Campbell and Lamar 2004; McCranie 2011).

Assigning protected areas for the conservation of cantil populations is not simply a matter of determining regions that exist within the range of the three species, as these have been shown to vary in their level of protection. Jaramillo et al. (2010: 650) presented a model that could be used to analyze systems of protected areas in Mesoamerica, and based on six requisites concluded that the system of protected areas in Panama is impressive due to the number of areas included and their collective territory; a detailed examination of the features, however, demonstrated that all but one of the 97 areas failed, to some degree, “in meeting the necessary requirements for the long-term protection of its biotic resources.” In Honduras, McCranie (2011) indicated that, “at

first glance, Honduras appears to have in place a robust system of protected areas, especially when compared to nearby countries. However, most of those areas exist on paper only.” Similarly, Acevedo et al. (2010) stated that, “the existing system of protected areas in Guatemala is insufficient to protect the country’s herpetofauna, because most of the legally designated areas must be considered as ‘paper parks’.” Essentially the same story can be told about systems of protected areas in other countries where cantils occur (see various chapters in Wilson

et al. 2010), an unfortunate aspect of reality in ongoing efforts to conserve biodiversity.

Unfortunately, because of the continuing destruction of natural habitats and the potential for the extirpation of cantil populations, the answers to some of the aforementioned questions are on the brink of being lost forever, if not lost already. This problem is critical, and we view it as a race against time to generate the necessary information that could help set aside protected areas to conserve disjunct and relictual populations of cantils for posterity.

Conservation Recommendations

Our recommendations for the long-term conservation of *A. bilineatus*, *A. howardgloydi*, *A. russeolus*, and *A. taylori* are as follows:

1. In light of the paucity of information regarding the relative health of populations of these species, it will be essential to undertake population assessments for all the cantils at or near localities where they have been recorded, most critically for *A. howardgloydi* and *A. russeolus* because of their relatively limited geographic ranges.
2. Once these surveys are completed, a conservation management plan should be developed to ascertain if populations of all four species are located within established protected areas, or if new areas should be considered. Such a plan is critical to the survival of cantils, especially since outside of protected areas these snakes generally are killed on sight or otherwise threatened by persistent habitat destruction or degradation.
3. Inasmuch as not all protected areas can be expected to provide adequate levels of protection to support viable populations of cantils, long-term population monitoring will be essential.
4. Given the elevation of these taxa to full species, conservation agencies can now use these vipers as “flagship species” in efforts to publicize conservation efforts in their respective countries at all levels of interest and concern, including education and ecotourism.
5. We recommend the establishment of zoo conservation (e.g., AZA) and outreach programs, such as those currently in progress for the venomous Guatemalan beaded lizard (e.g., www.ircf.org; see Domínguez-Vega et al. 2012) and a wide variety of highly endangered anuran species (e.g., www.zooatlanta.org). Captive assurance colonies might help maximize future options for the recovery of wild populations.
6. One major conclusion of this paper is that our knowledge of the taxonomy and phylogeography of cantils remains at an elementary level. Thus, as conservation assessments proceed, it will be important to obtain tissue samples from a sufficiently broad array of populations to allow for more robust molecular analyses. Similarly, we need more detailed morphological assessments and more sophisticated levels of analyses, such as geometric morphometric approaches (Davis 2012).

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*This paper is part of a special issue of *Amphibian & Reptile Conservation* that deals with the herpetofauna of Mexico. In addition to Dr. Conant’s seminal work on *Agkistrodon* (with Dr. Howard K. Gloyd), readers should be reminded that he also produced important works on this country’s *Nerodia* (then *Natrix*) and *Thamnophis*.

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Taxonomy and conservation of the common cantil



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Larry David Wilson is a herpetologist with lengthy experience in Mesoamerica, totaling six collective years (combined over the past 47). Larry is the senior editor of the recently published *Conservation of Mesoamerican Amphibians and Reptiles* and a co-author of seven of its chapters. He retired after 35 years of service as Professor of Biology at Miami-Dade College in Miami, Florida. Larry is the author or co-author of more than 290 peer-reviewed papers and books on herpetology, including the 2004 *Amphibian & Reptile Conservation* paper entitled “The conservation status of the herpetofauna of Honduras.” His other books include *The Snakes of Honduras*, *Middle American Herpetology*, *The Amphibians of Honduras*, *Amphibians & Reptiles of the Bay Islands and Cayos Cochinos, Honduras*, *The Amphibians and Reptiles of the Honduran Mosquitia*, and *Guide to the Amphibians & Reptiles of Cusuco National Park, Honduras*. He also served as the Snake Section Editor for the Catalogue of American Amphibians and Reptiles for 33 years. Over his career, Larry has authored or co-authored the descriptions of 69 currently recognized herpetofaunal species and six species have been named in his honor, including the anuran *Craugastor lauraster* and the snakes *Cerrophidion wilsoni*, *Myriopholis wilsoni*, and *Oxybelis wilsoni*.



Gordon W. Schuett is an evolutionary biologist and herpetologist who has conducted extensive research on reptiles. His work has focused primarily on venomous snakes, but he has also published on turtles, lizards, and amphibians. His most significant contributions to date have been studies of winner-loser effects in agonistic encounters, mate competition, mating system theory, hormone cycles and reproduction, caudal luring and mimicry, long-term sperm storage, and as co-discoverer of facultative parthenogenesis in non-avian reptiles. He served as chief editor of the peer-reviewed book *Biology of the Vipers* and is presently serving as chief editor of an upcoming peer-reviewed book *The Rattlesnakes of Arizona* (rattlesnakesofarizona.org). Gordon is a Director and scientific board member of the newly founded non-profit *The Copperhead Institute* (copperheadinstitute.org). He was the founding Editor of the journal *Herpetological Natural History*. Dr. Schuett is an adjunct professor in the Department of Biology at Georgia State University.



Randall S. Reiserer is an integrative biologist whose research focuses on understanding the interrelationships among ecology, morphology, and behavior. Within the broad framework of evolutionary biology, he studies cognition, neuroscience, mimicry, life-history evolution, and the influence of niche dynamics on patterns of evolutionary change. His primary research centers on reptiles and amphibians, but his academic interests span all major vertebrate groups. His studies of behavior are varied and range from caudal luring and thermal behavior in rattlesnakes to learning and memory in transgenic mice. His studies of caudal luring in snakes established methods for studying visual perception and stimulus control. He commonly employs phylogenetic comparative methods and statistics to investigate and test evolutionary patterns and adaptive hypotheses. Dr. Reiserer is an editor of the upcoming peer-reviewed book, *The Rattlesnakes of Arizona*.

Appendix 1. Morphological characters of the subspecies of *Agkistrodon bilineatus* (ingroup) and two outgroups (*A. contortrix* and *A. piscivorus*) used for character mapping analysis in this study. Unless otherwise indicated, characters are based on adult stages. *Not used in analysis.

Ingroup (cantils)

Agkistrodon bilineatus bilineatus

Upper facial stripe (lateral view): relatively broad and white.

Lower facial stripe (lateral view): relatively broad and continuous with dark pigment below; white.*

Dorsal coloration of adults: very dark brown to black; crossbands usually absent; if present, difficult to distinguish; pattern composed of small white spots or streaks.

Chin and throat: dark brown or black, with narrow white lines or markings.

Venter: dark brown or black with pale markings.*

Coloration of neonates/juveniles: some shade of brown with crossbands separated by a paler ground color; lateral edges of crossbands flecked with white.

Tail tip of neonates: bright yellow.

Sexual color dimorphism: absent.

Agkistrodon bilineatus howardgloydi

Upper facial stripe (lateral view): narrow and white; posterior portion often absent in adults.

Lower facial stripe (lateral view): broader than upper stripe, and divided into two components; stripe bordered below by dark line, followed by pale pigment to lower edge of supralabials; white.*

Dorsal coloration of adults: reddish brown or brown; pattern of dark crossbands contrasts moderately with dorsal ground color.

Chin and throat: orange yellow, bright orange, or brownish orange with few white spots.

Venter: dark reddish brown.*

Coloration of neonates/juveniles: tan to reddish orange, or reddish, with reddish brown crossbands edged intermittently with white and/or black, especially as they approach venter.

Tail tip of neonates/juveniles: banded with sequential pattern ranging from very dark gray anteriorly to paler gray toward the tip, with interspaces alternating from pale gray to white.

Sexual color dimorphism: moderate sexual color dimorphism present in sub-adults and adults.

Agkistrodon bilineatus russeolus

Upper facial stripe (lateral view): narrow and white; sometimes intermittent posterior to eye.

Lower facial stripe (lateral view): broader than upper stripe and continuous, with narrow band of dark pigment below; white.*

Dorsal coloration of adults: pale reddish brown; broad deep reddish brown to brown crossbands separated by paler areas, and strongly edged irregularly with white; crossbands remain apparent, even in older adults; laterally, centers of crossbands paler and usually contain one or two dark spots.

Chin and throat: pattern often reduced; small whitish spots or lines evident on a darker background.

Venter: approximately the median third is not patterned.*

Coloration of neonates/juveniles: pattern of brown crossbands with paler brown interspaces; banding intermittently edged with white; with growth, inner portion of crossbands turns same color as interspaces, thereby developing a highly fragmented pattern.

Tail tip of neonates/juveniles: pale gray with faint white banding; darker gray tones evident with growth.

Sexual color dimorphism: absent.

Agkistrodon taylori

Upper facial stripe (lateral view): relatively broad and white.

Lower facial stripe (lateral view): broad and continuous, and extends to lower edge of supralabials.

Dorsal coloration of adults: pronounced black crossbands separated by gray, pale brown, or lavender areas that often contain yellow-brown or orange.*

Chin and throat: bold markings, with white, yellow and or orange elements.

Venter: dark gray or black markings arranged in a somewhat checkerboard pattern.

Coloration of neonates/juveniles: strongly patterned, but with markings like those of adults but less intense.

Tail tip of neonates/juveniles: yellow (rarely, white).

Sexual color dimorphism: present in all age classes; sometimes difficult to detect in older adults that darken.

Outgroups

Agkistrodon piscivorus (outgroup 1)

Upper facial stripe (lateral view): variable in size and appearance; pale but not white.

Lower facial stripe (lateral view): relatively broad and continuous with dark pigment below.*

Dorsal coloration of adults: very dark brown to black; crossbands present in some populations, difficult to distinguish; pattern composed of small white spots or streaks.

Chin and throat: pale, cream to white.

Venter: dark brown or black with pale markings.*

Coloration of neonates/juveniles: pale ground color with pronounced bands; strong ontogenetic change

Tail tip of neonates: bright yellow.

Sexual color dimorphism: absent.

Agkistrodon contortrix (outgroup 2)

Upper facial stripe (lateral view): absent.

Lower facial stripe (lateral view): absent.*

Dorsal coloration of adults: light tan ground color; brown crossbands of varying size present.

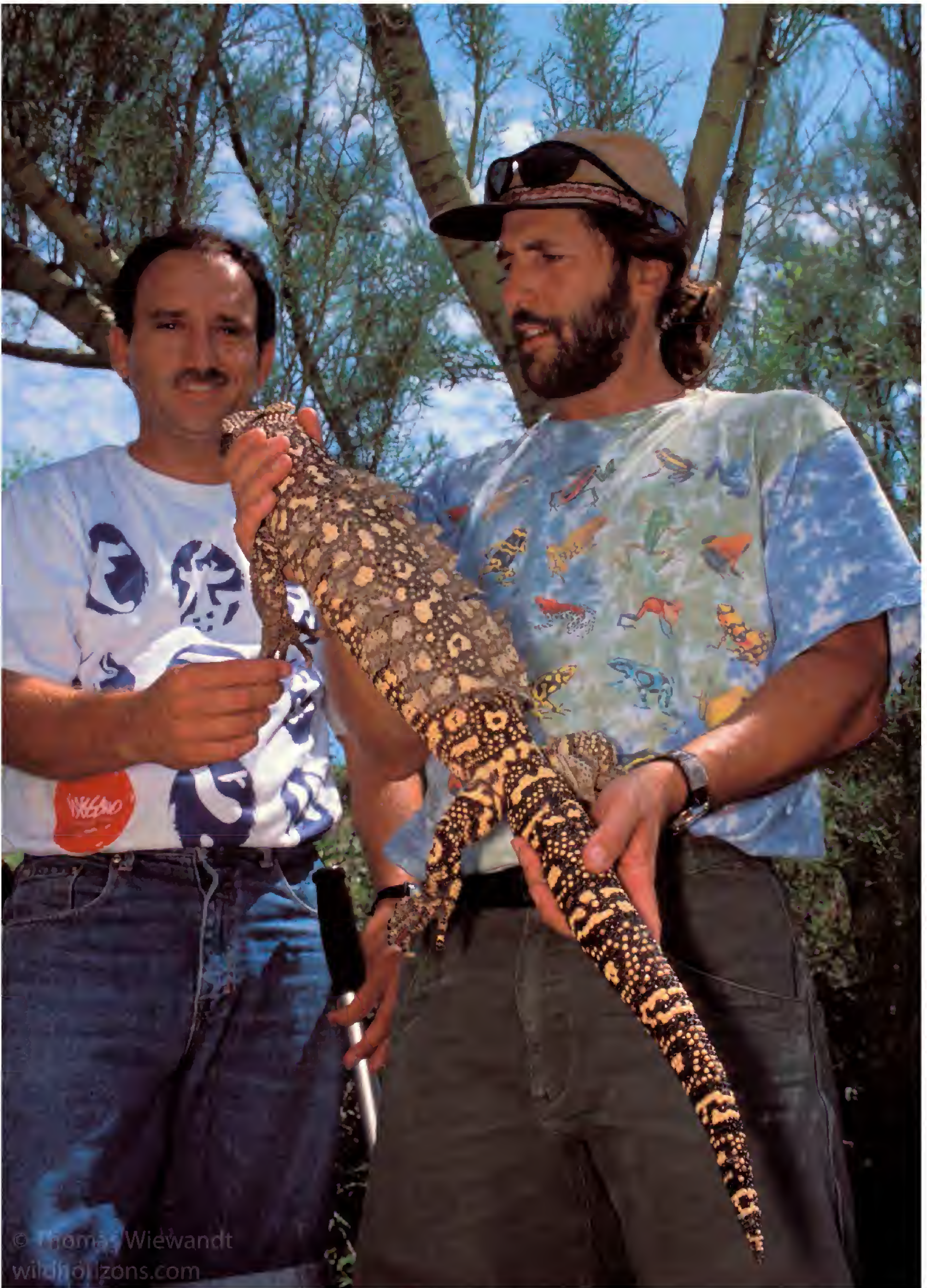
Chin and throat: tan; typically same as ground color of face and dorsum.

Venter: pale tan with dark tan markings.*

Coloration of neonates/juveniles: ground color pale tan; similar to adults but subdued.

Tail tip of neonates: bright yellow.

Sexual color dimorphism: absent.



Dr. Daniel D. Beck (right) with Martin Villa at the Centro Ecologia de Sonora, in Hermosillo, Mexico. Dr. Beck is holding a near-record length Río Fuerte beaded lizard (*Heloderma horridum exasperatum*). Photo by Thomas Wiewandt.

Taxonomic reassessment and conservation status of the beaded lizard, *Heloderma horridum* (Squamata: Helodermatidae)

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Abstract.—The beaded lizard (*Heloderma horridum*) and Gila monster (*H. suspectum*) are large, highly venomous, anguimorph lizards threatened by human persecution, habitat loss and degradation, and climate change. A recent DNA-based phylogenetic analysis of helodermatids (Douglas et al. 2010. *Molecular Phylogenetics and Evolution* 55: 153–167) suggests that the current infraspecific taxonomy (subspecies) of beaded lizards underestimates their biodiversity, and that species status for the various subspecies is warranted. Those authors discussed “conservation phylogenetics,” which incorporates historical genetics in conservation decisions. Here, we reassess the taxonomy of beaded lizards utilizing the abovementioned molecular analysis, and incorporate morphology by performing a character mapping analysis. Furthermore, utilizing fossil-calibrated sequence divergence results, we explore beaded lizard diversification against a backdrop of the origin, diversification, and expansion of seasonally dry tropical forests (SDTFs) in Mexico and Guatemala. These forests are the primary biomes occupied by beaded lizards, and in Mesoamerica most are considered threatened, endangered, or extirpated. Pair-wise net sequence divergence (%) values were greatest between *H. h. charlesbogerti* and *H. h. exasperatum* (9.8%), and least between *H. h. alvarezi* and *H. h. charlesbogerti* (1%). The former clade represents populations that are widely separated in distribution (eastern Guatemala vs. southern Sonora, Mexico), whereas in the latter clade the populations are much closer (eastern Guatemala vs. Chiapas, Mexico). The nominate subspecies (*Heloderma h. horridum*) differed from the other subspecies of *H. horridum* at 5.4% to 7.1%. After diverging from a most-recent common ancestor ~35 mya in the Late Eocene, subsequent diversification (cladogenesis) of beaded lizards occurred during the late Miocene (9.71 mya), followed by a lengthy stasis of up to 5 my, and further cladogenesis extended into the Pliocene and Pleistocene. In both beaded lizards and SDTFs, the tempo of evolution and diversification was uneven, and their current distributions are fragmented. Based on multiple lines of evidence, including a review of the use of trinomials in taxonomy, we elevate the four subspecies of beaded lizards to full species: *Heloderma alvarezi* (Chiapan beaded lizard), *H. charlesbogerti* (Guatemalan beaded lizard), *H. exasperatum* Río Fuerte beaded lizard), and *H. horridum* (Mexican beaded lizard), with no changes in their vernacular names. Finally, we propose a series of research programs and conservation recommendations.

Key words. mtDNA, ATPase, nuclear genes, character mapping, genomics, seasonally dry tropical forests, reptiles

Resumen.—El escorpión (*Heloderma horridum*) y el monstruo de Gila (*H. suspectum*) son lagartijas grandes, anguimorfas, y muy venenosas que están sufriendo diversas amenazas como resultado de la persecución humana, degradación y pérdida del hábitat y el cambio climático global. Un análisis filogenético reciente basado en ADN de este grupo (Douglas et al. 2010. *Molecular Phylogenetics and Evolution* 55: 153–167) sugiere que la actual taxonomía intraespecífica (subespecies) del escorpión está subestimando la diversidad biológica, y el reconocimiento de especies es justificable. Estos autores discuten la utilidad del enfoque denominado “conservación filogenética”, que hace hincapié en la incorporación de la genética histórica en las decisiones de conservación. En este estudio, reevaluamos la taxonomía del escorpión utilizando el análisis molecular antes mencionado e incorporamos la morfología en un análisis de mapeo de caracteres. Así mismo, con los resultados de la secuencia de divergencia calibrada con fósiles, se explora la diversificación del escorpión en forma yuxtapuesta al origen, la diversificación y la expansión de los bosques tropicales estacionalmente secos (SDTFs) en México y Guatemala. Estos bosques son los principales biomas ocupados por los escorpiones, y en Mesoamérica la mayoría son considerados amenazados, en peligro o

extirpados. Los valores de la secuencia de divergencia neta por pares (%) fueron mayores entre *H. h. charlesbogerti* y *H. h. exasperatum* (9,8%) y menores entre *H. h. alvarezí* y *H. h. charlesbogerti* (1%). El primer grupo representa a poblaciones que están muy distantes una de la otra en su distribución (este de Guatemala vs. sur de Sonora, México), mientras que las poblaciones en el segundo grupo están mucho más relacionadas (este de Guatemala vs. Chiapas, México). La subespecie denominada (*Heloderma h. horridum*) difirió de las otras subespecies de *H. horridum* entre un 5,4% a 7,1%. Después de la separación de un ancestro común más reciente, ~35 mda a finales del Eoceno, ocurrió una diversificación (cladogénesis) posterior de *Heloderma* a finales del Mioceno tardío (9,71 mda), seguida de un estancamiento prolongado de hasta 5 mda, con una cladogénesis posterior que se extendió hasta el Plioceno y Pleistoceno. En ambos grupos, escorpiones y bosques tropicales estacionalmente secos, los procesos de evolución y diversificación fueron desiguales, y su distribución fue fragmentada. Hoy en día, el escorpión está distribuido de manera irregular a lo largo de su amplio rango geográfico. Basándonos en varias líneas de evidencia, incluyendo una revisión del uso de trinomios taxonómicos, elevamos las cuatro subespecies del escorpión al nivel de especie: *Heloderma alvarezí* (escorpión de Chiapas), *H. charlesbogerti* (escorpión Guatemalteco), *H. exasperatum* (escorpión del Río Fuerte), y *H. horridum* (escorpión Mexicano), sin cambios en los nombres vernáculos. Por último, proponemos una serie de programas de investigación y recomendaciones para su conservación.

Palabras claves. ADNmt, ATPasas, genes nucleares, mapeo de caracteres, genómica, bosque tropical estacionalmente seco, reptiles

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The century-long debate over the meaning and utility of the subspecies concept has produced spirited print but only superficial consensus. I suggest that genuine consensus about subspecies is an impossible goal ... the subspecies concept itself is simply too heterogeneous to be classified as strict science.

Fitzpatrick 2010: 54.

Introduction

The beaded lizard (*Heloderma horridum*) is a large, highly venomous, anguimorph (Helodermatidae) squamate with a fragmented distribution in Mesoamerica that extends from northwestern Mexico (Sonora, Chihuahua) to eastern Guatemala (Bogert and Martín del Campo 1956; Campbell and Vannini 1988; Campbell and Lamar 2004; Beck 2005; Beaman et al. 2006; Anzueto and Campbell 2010; Wilson et al. 2010, 2013; Domínguez-Vega et al. 2012). Among the reptilian fauna of this region, the beaded lizard (in Spanish, known as the “escorpión”) is well known to local inhabitants, yet its natural history is surrounded by mystery, notoriety and misconception. Consequently, it is frequently slaughtered when encountered (Beck 2005).

Adding to this anthropogenic pressure, beaded lizard populations, with rare exceptions (Lemos-Espinal et al. 2003; Monroy-Vilchis et al. 2005), occur primarily in seasonally dry tropical forests, SDTFs (Campbell and Lamar 2004; Beck 2005; Campbell and Vannini 1988; Domínguez-Vega et al. 2012), the most endangered

biome in Mesoamerica owing to persistent deforestation for agriculture, cattle ranching, and a burgeoning human population (Janzen 1988; Myers et al. 2000; Trejo and Dirzo 2000; Hoekstra et al. 2005; Miles et al. 2006; Stoner and Sánchez-Azofeifa, 2009; Williams-Linera and Lorea 2009; Beck 2005; Pennington et al. 2006; Wilson et al. 2010, 2013; Dirzo et al. 2011; De-Nova et al. 2012; Domínguez-Vega et al. 2012; Golicher et al. 2012). Furthermore, drought and fires escalate the above threats (Beck 2005; Miles et al. 2006), and recent predictive models of climate change show that the persistence of SDTFs in this region is highly dubious (Trejo and Dirzo 2000; Miles et al. 2006; Golicher et al. 2012).

Despite its large size and charismatic nature, our knowledge of the ecology, geographical distribution, and status of populations of *H. horridum* remains limited (Beck and Lowe 1991; Beck 2005; Ariano-Sánchez 2006; Douglas et al. 2010; Domínguez-Vega et al. 2012). Furthermore, based on multiple lines of evidence, a taxonomic reevaluation of this group of lizards is long overdue (Beck 2005; Douglas et al. 2010).

Here, we continue the dialogue concerning the infra-specific (subspecific) taxonomy and conservation status of beaded lizards. We reviewed recent publications by Beck (2005) and Domínguez-Vega et al. (2012), and augment their conclusions based on personal (DDB) field research in Mexico. We reassess the taxonomic status of the populations of *H. horridum* using morphology, biogeography, and a recent molecular-based (mtDNA, nDNA) analysis conducted by Douglas et al. (2010). Although Douglas et al. (2010) commented on the mo-

lecular diversity of *Heloderma*, especially in *H. horridum*, they did not provide explicit taxonomic changes. In this paper, therefore, we reevaluate and expand upon their conclusions. To gain insights into phenotypic (morphological) evolution of extant *Heloderma*, with emphasis on *H. horridum*, we conduct a character mapping analysis (Brooks and McLennan 1991; Harvey and Pagel 1991; Martins 1996; Maddison and Maddison 2011), utilizing the phylogenetic information (trees) recovered by Douglas et al. (2010).

Overview of Morphology and Molecules in the genus *Heloderma*

1. Morphological assessment

Published over half a century ago, Bogert and Martín del Campo's (1956) detailed and expansive monograph of extant and fossil helodermatid lizards remains the definitive morphological reference (reviewed in Campbell and Lamar, 2004; Beck, 2005), and it contains the diagnoses and descriptions of two new subspecies (*Heloderma horridum alvarezii* and *H. h. exasperatum*). Thirty-two years later, Campbell and Vannini (1988) described a new subspecies (*H. h. charlesbogerti*), from the Río Motagua Valley in eastern Guatemala, in honor of Charles Bogert's pioneering work on these lizards. With few exceptions, such as Conrad et al. (2010) and Gauthier et al. (2012), who examined higher-level relationships of the Helodermatidae and other anguimorphs, a modern phylogeographic analysis of morphological diversity for extant helodermatids is lacking. However, as we illustrate in our character mapping analysis, the morphological characters used by Bogert and Martín del Campo (1956) in diagnosing and describing the subspecies of beaded lizards, though somewhat incomplete, remains useful in analyzing phenotypic variation.

2. Diagnosis, description, and distribution of *Heloderma horridum*

Diagnosis and description.—Bogert and Martín del Campo (1956) and Campbell and Vannini (1988) provided diagnoses and descriptions of the subspecies of *Heloderma horridum*. Recent information on the biology, systematics, and taxonomy of *H. horridum* and *H. suspectum* is summarized and critiqued by Campbell and Lamar (2004) and Beck (2005), and Beaman et al. (2006) provided a literature reference summary of the Helodermatidae. Presently, four subspecies of *H. horridum* are recognized (Figs. 1–5).

Mexican beaded lizard: *H. h. horridum* (Wiegmann 1829)

Río Fuerte beaded lizard: *H. h. exasperatum* Bogert and Martín del Campo 1956

Chiapan beaded lizard: *H. h. alvarezii* Bogert and Martín del Campo 1956

Guatemalan beaded lizard: *H. h. charlesbogerti* Campbell and Vannini 1988

The four subspecies of *H. horridum* were diagnosed and described on the basis of scutellation, color pattern, and geographical distribution, and we refer the reader to the aforementioned works for detailed descriptions and taxonomic keys. The characters used by Bogert and Martín del Campo (1956) and Campbell and Vannini (1988) to diagnose the subspecies have been reevaluated as to their stability, albeit informally (Campbell and Lamar 2004; Beck 2005). Poe and Wiens (2000) and Douglas et al. (2007) discussed the problem of character stability in phylogenetic analyses. Kraus (1988), for example, commented that reasonable evidence for character stability, and thus its usefulness as a shared-derived character (apomorphy), was the occurrence of a discrete trait in adults at a frequency of 80% or greater. In our character mapping analysis using published morphological characters (discussed below), character stability was a major assumption. Consequently, further research is warranted for substantiation.

Geographic distribution.—The geographic distribution of *Heloderma horridum* extends from southern Sonora and adjacent western Chihuahua, in Mexico, southward to eastern and southern Guatemala (Campbell and Lamar 2004; Beck 2005; Anzueto and Campbell 2010; Domínguez-Vega et al. 2012).

The Río Fuerte Beaded Lizard (*H. h. exasperatum*) inhabits the foothills of the Sierra Madre Occidental, within the drainage basins of the Río Mayo and Río Fuerte of the Sonoran-Sinaloan transition subtropical dry forest in southern Sonora, extreme western Chihuahua, and northern Sinaloa (Campbell and Lamar 2004; Beck 2005). Its distribution closely matches the fingers of SDTFs within this region, but it has also been encountered in pine-oak forest at 1,400 m near Alamos, Sonora (Schwalbe and Lowe 2000). Bogert and Martín del Campo (1956) commented that as far as their records indicated, a considerable hiatus existed between the distribution of *H. h. exasperatum* (to the north) and *H. h. horridum* (to the south), but owing to the narrow contact between the supranasal and postnasal in *H. h. horridum* from Sinaloa, intergradation might be found in populations north of Mazatlán. Based on this information, Beck (2005: 24) stated, "...in tropical dry forest habitats north of Mazatlán, Sinaloa, *H. h. exasperatum* likely intergrades with *H. h. horridum*." Definitive data on intergradation remains unreported, however, and published distribution maps have incorporated that assumption (e.g., Campbell and Lamar 2004; Beck 2005). Campbell and Lamar (2004, p. 104) show a single example of *H. suspectum* from El Dorado in west-central Sinaloa, Mexico (deposited in the American Museum of Natural History [90786]), a locality 280 km south from northern records in Río del Fuerte, Sinaloa.



Fig. 1. A. Adult Río Fuerte beaded lizard (*Heloderma horridum exasperatum*) in a defensive display (Alamos, Sonora). B. Adult Río Fuerte beaded lizard raiding a bird nest (Alamos, Sonora). Photos by Thomas Wiewandt.



Fig. 2. Adult Mexican beaded lizard (*H. h. horridum*) observed on 11 July 2011 at Emiliano Zapata, municipality of La Huerta, coastal Jalisco, Mexico. Photo by Javier Alvarado.



Fig. 3. Adult Chiapan beaded lizard (*Heloderma horridum alvarezii*) from Sumidero Canyon in the Río Grijalva Valley, east of Tuxtla Gutiérrez, Chiapas, Mexico. Photo by Thomas Wiewandt.



Fig. 4. Adult Guatemalan beaded lizard (*Heloderma horridum charlesbogerti*) from the Motagua Valley, Guatemala. Photo by Daniel Ariano-Sánchez.

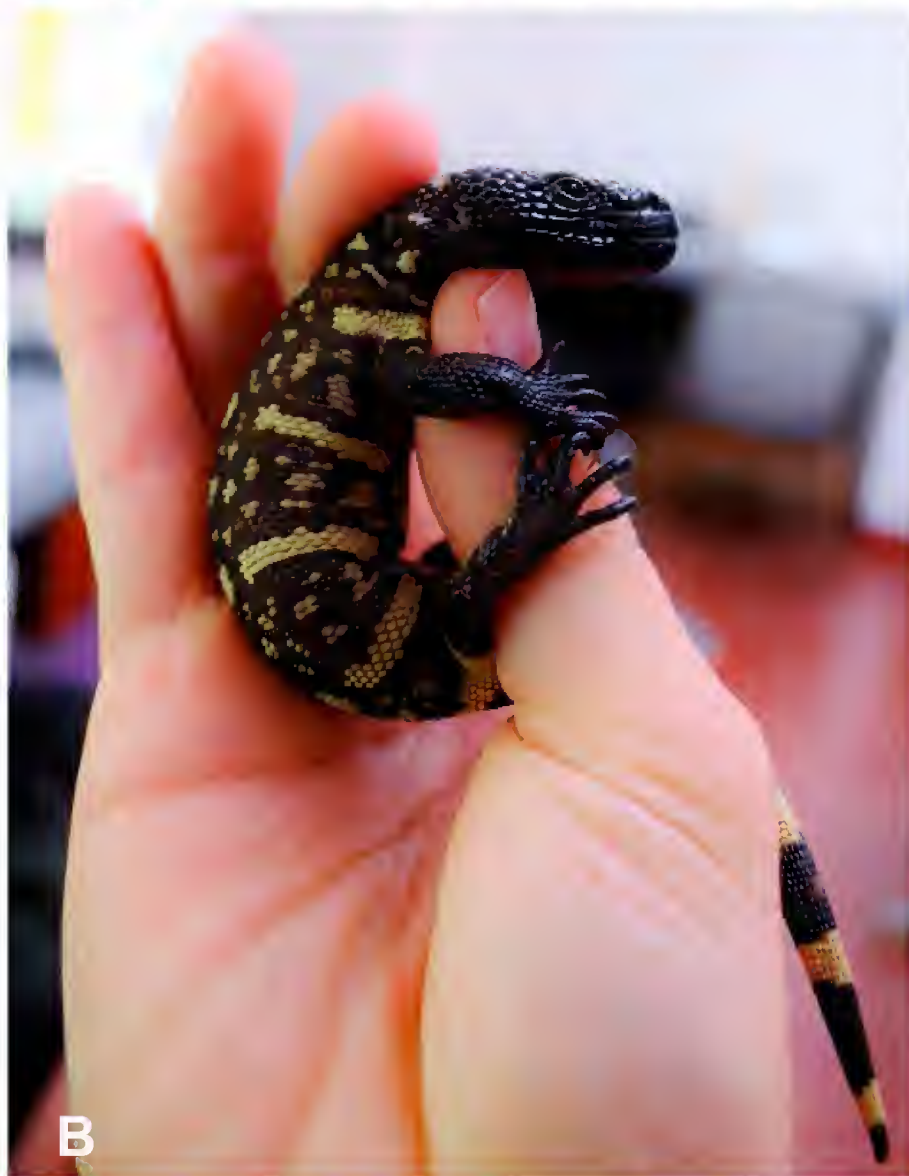


Fig. 5. A. Juvenile *Heloderma horridum exasperatum* (in situ, Álamos, Sonora, Mexico). Photo by Stephanie Meyer.

B. Neonate *Heloderma h. horridum* (wild-collected July 2011, Chamela, Jalisco). Photo by Kerry Holcomb.

C. Neonate *Heloderma horridum alvarezii* (Río Lagartero Depression, extreme western Guatemala). Photo by Quetzal Dwyer.

D. Neonate *Heloderma horridum charlesbogerti* (hatched at Zoo Atlanta in late 2012). Photo by David Brothers, courtesy of Zoo Atlanta.

Owing to this unusual location, we suggest a re-examination of this museum specimen to verify its identity. Neonates and juveniles of *H. h. exasperatum* resemble adults in color pattern (Fig. 5a), but they show greater contrast (i.e., a pale yellow to nearly white pattern on a ground color of brownish-black). Also, their color pattern can be distinguished from that of adults (e.g., no yellow speckling between the tail bands), and an ontogenetic increase in yellow pigment occurs (Bogert and Martín del Campo 1956; Beck 2005).

The Mexican beaded lizard (*H. h. horridum*), the subspecies with the most extensive distribution, occurs primarily in dry forest habitats from southern Sinaloa southward to Oaxaca, including the states of Jalisco, Nayarit, Colima, Michoacán, and Guerrero, and inland into the states of México and Morelos (Campbell and Lamar 2004; Beck 2005). Monroy-Vilchis et al. (2005)

recorded an observation of this taxon at mid elevations (e.g., 1861 m) in pine-oak woodlands in the state of México. Campbell and Vannini (1988), citing Álvarez del Toro (1983), indicated the probability of areas of intergradation between *H. h. horridum* and *H. h. alvarezii*, in the area between the Isthmus of Tehuantepec and Cintalapa, Chiapas. Nonetheless, Álvarez del Toro (1983) stated that individuals of beaded lizards with yellow markings (a coloration character present in *H. h. horridum*) are found in the region from Cintalapa to the Isthmus of Tehuantepec, as well as in dry areas along the coast from Arriaga (near the Isthmus of Tehuantepec) to Huixtla (near the Guatemalan border). Literature information on intergradation between these two subspecies is inconclusive and, therefore, will require further investigation. Neonates and juveniles of *H. h. horridum*, like those of *H. h. exasperatum*, resemble adults in color pattern (Fig. 5b), but their color contrast is greater (Bogert and Martín del Campo 1956; Beck 2005).

The Chiapan beaded lizard (*H. h. alvarezii*) inhabits dry forests in the Central Depression (Río Grijalva

Depression) of central Chiapas and the Río Lagartero Depression in extreme western Guatemala (Campbell and Lamar 2004; Beck 2005; Johnson et al. 2010; Wilson et al. 2010: p. 435). This taxon is unique among the subspecies in that it undergoes an ontogenetic increase in melanism, whereby it tends to lose the juvenile color pattern (Bogert and Martín del Campo 1956; Beck 2005). Neonates and juveniles often are distinctly marked with yellow spots and bands, including on the tail (Fig. 5c), whereas the color pattern of adults gradually transforms to an almost uniform dark brown or gray. Black individuals, however, are uncommon. Yellow banding on the tail, a characteristic typical of the other subspecies of beaded lizards, (Fig. 2), is essentially absent in adults (Bogert and Martín del Campo 1956; Beck 2005).

The Guatemalan beaded lizard (*H. h. charlesbogerti*) inhabits the Río Motagua Valley, in the Atlantic versant of eastern Guatemala (Campbell and Vannini 1988). Recently, however, Anzueto and Campbell (2010) reported three specimens from two disjunct populations on the Pacific versant of Guatemala, to the southwest of the Motagua Valley. Neonates resemble adults in color pattern, though they tend to be paler (Fig. 5d).

In summary, the distribution of *H. horridum* is fragmented throughout its extensive range and corresponds closely with the patchy distribution of SDTFs in Mexico and Guatemala (Beck 2005; Miles et al. 2006; Domínguez-Vega et al. 2012). The distribution of the Guatemalan beaded lizard (*H. h. charlesbogerti*) is distinctly allopatric (Campbell and Vannini 1988; Beck 2005; Ariano-Sánchez 2006; Anzueto and Campbell 2010).

3. Molecular assessment

Douglas et al. (2010) provided the first detailed molecular-based (mtDNA, nDNA) analysis of the phylogeographic diversity of helodermatid lizards, which is available at www.cnah.org/cnah_pdf.asp. Two authors (GWS, DDB) of this paper were co-authors. Specifically, Douglas et al. (2010) used a “conservation phylogenetics” approach (Avice 2005, 2008; Avice et al. 2008), which combines and emphasizes the principles and approaches of genetics and phylogeography and how they can be applied to describe and interpret biodiversity.

Methods.—Douglas et al. (2010) sampled 135 locality-specific individuals of *Heloderma* (48 *H. horridum*, 87 *H. suspectum*) from throughout their range (their ingroup). The outgroup taxa included multiple lineages of lizards and snakes, with an emphasis on anguimorphs. Based on both morphological and DNA-based analyses, all authorities have recognized the extant helodermatid lizards as monotypic (a single genus, *Heloderma*), and as members of a larger monophyletic assemblage of lizards termed the Anguimorpha (Pregill et al. 1986; Estes et al. 1988; Townsend et al. 2004; Wiens et al. 2010, 2012; Gauthier et al. 2012). This lineage includes the well-known varanids (*Varanus*), alligator lizards and their relatives

(Anguidae), as well as such relatively obscure taxa as the Old World Lanthanotidae (*Lanthanotus*) and Shinisauridae (*Shinisaurus*), and the New World Xenosauridae (*Xenosaurus*). The mtDNA analyses in Douglas et al. (2010) were rooted with the tuatara (*Sphenodon punctatus*), and Bayesian and maximum parsimony (MP) analyses were conducted using Mr. Bayes (Hulsenbeck and Rohnquist 2001).

Douglas et al. (2010) used sequence data from both mitochondrial (mt) DNA and nuclear (n) DNA as molecular markers in their phylogenetic analyses. Specifically, they discussed reasons for selecting mtDNA regions ATPase 8 and 6, and the nDNA introns alpha-enolase (ENOL) and ornithine decarboxylase (OD). The utility of combining mt- and nDNAs (supertree) in recovering phylogenetic signals has been discussed (Douglas et al. 2007, 2010), yet each of these markers and the procedure of combining sequence data have both benefits and pitfalls (Wiens 2008; Castoe et al. 2009). Long-branch attraction and convergence, for example, can result in misleading relationships (Bergsten 2005; Wiens 2008; Castoe et al. 2009). The tools for detecting and potentially correcting these problems have been discussed (e.g., Castoe et al. 2009; Assis and Rieppel 2011).

Results and discussion.—Douglas et al. (2010) recovered the genus *Heloderma* as monophyletic (Helodermatidae), with *H. horridum* and *H. suspectum* as sister taxa. In a partitioned Bayesian analysis of mtDNA, Helodermatidae was recovered as sister to the anguimorph clade (*Shinisaurus* (*Abronia* + *Elgaria*)), which in turn was sister to the clade *Lanthanotus* + *Varanus*. Recent molecular studies of squamates by Wiens et al. (2012, see references therein) recovered a similar topology to that of Douglas et al. (2010). However, an extensive morphological analysis by Gauthier et al. (2012) supported a traditional topology of *Heloderma* as sister to varanids and *Lanthanotus borneensis* (see Estes et al. 1986; Pregill et al. 1988). In Douglas et al. (2010), a partitioned Bayesian analysis of the nuclear marker alpha-enolase (intron 8 and exon 8 and 9), however, recovered *Heloderma* as sister to a monophyletic *Varanus*. Using a combined analysis of morphology (extant and fossil data), mitochondrial, and nuclear markers, Lee (2009) recovered Varanidae as sister to the clade Helodermatidae + Anguidae. In a combined approach, Wiens et al. (2010) recovered results that were similar to those of Lee (2009). A recent DNA-based analysis of Squamata by Pyron et al. (2013) examined 4151 species (lizards and snakes), and they recovered Helodermatidae as sister to the clade Anniellidae + Anguidae. Moreover, they recovered the clade Varanidae + Lanthanotidae as sister to Shinisauridae.

How do systematists deal with this type of incongruity (discordance) in studies that use different types (e.g., morphology vs. molecular) of phylogenetic markers? Recently, Assis and Rieppel (2011) and Losos et al. (2012) discussed the common occurrence of discordance between molecular and morphological phylogenetic

analyses. Specifically, with respect to discordance, As-
sis and Rieppel (2011) stated that, “...the issue is not to
simply let the molecular signal override the morphological
one. The issue instead is to make empirical evidence
scientific by trying to find out why such contrastive
signals are obtained in the first place.” We concur with
their opinions, and thus further research is warranted to
resolve such conflicts in the phylogeny of anguimorph
squamates.

Relationships among the four subspecies of *H. hor-
ridum* recovered in the analysis by Douglas et al. (2010,
p. 158–159, fig. 3a, b) are depicted in Fig. 6. This topol-
ogy was derived from a partitioned Bayesian analysis of
the mtDNA regions ATPase 8 and 6. The Gila monster
(*H. suspectum*) was the immediate outgroup. Two sets of
sister pairs of beaded lizards were recovered: *H. h. exas-
peratum* (HHE) + *H. h. horridum* (HHH), and *H. h. al-
varezi* (HHA) + *H. h. charlesbogerti* (HHC). The current
subspecific designations for *H. horridum* were robustly
supported (concordant) by these genetic analyses. Un-
like results obtained for Gila monsters (*H. suspectum*),
haplotype and genotype data for *H. horridum* were both
diverse and highly concordant with the designated sub-
species and their respective geographic distributions.

Douglas et al. (2010) generated pair-wise net sequence
divergence (%) values based on their recovered relation-
ships (Table 1, Fig. 6). The greatest divergence was be-
tween HHE and HHC (9.8%), and the least between HHA

and HHC (1%). The former pair represents populations
widely separated in distribution (southern Sonora, Mex-
ico vs. eastern Guatemala), whereas the latter are much
more closely distributed (Chiapas, Mexico vs. eastern
Guatemala). The nominate subspecies (*Heloderma h.
horridum*) differed from the other three subspecies of
beaded lizards, from 5.4% to 7.1%.

Table 1. Pair-wise net sequence divergence (%) values between
the four subspecies of the beaded lizard (*Heloderma horridum*)
derived from a partitioned Bayesian analysis of the mtDNA re-
gions ATPase 8 and 6 (modified from Douglas et al. 2010, pp.
157–159, 163; fig. 3a, b, tables 1 and 3). Values in parentheses
denote evolutionary divergence times, which represent mean
age. Mean age is the time in millions of years (mya) since the
most-recent common ancestor (tree node) and is provided for
the sister clades HHE-HHH and HHA-HHC (Fig. 6). Beaded
lizards and Gila monsters (*H. suspectum*) are hypothesized
to have diverged from a most-recent common ancestor in the
late Eocene ~35 mya (Douglas et al. 2010, p. 163). Percent se-
quence divergence was greatest for HHC-HHE, and was lowest
for HHA-HHC. See text for further details.

	HHA	HHC	HHE	HHH
HHA	—			
HHC	1% (3.02)	—		
HHE	9.3%	9.8%	—	
HHH	5.4%	6.2%	7.1% (4.42)	—

HHA = *H. h. alvarezi*; HHC = *H. h. charlesbogerti*; HHE = *H. h. exas-
peratum*; HHH = *H. h. horridum*.

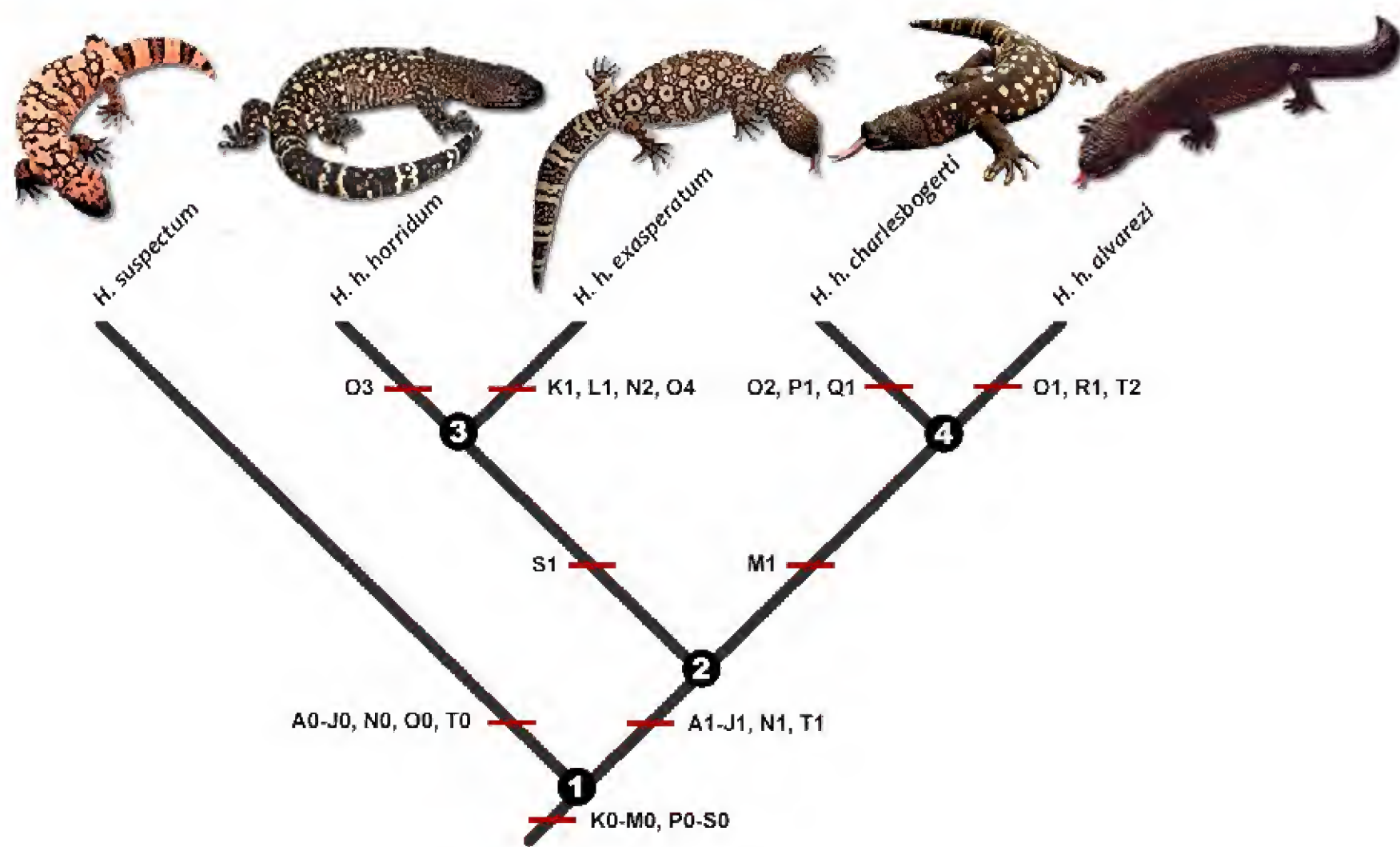


Fig. 6. Character mapping analysis. Tree topology and node dates based on Douglas et al. (2010). Morphological characters (Table 2) were mapped via parsimony and outgroup methods using the software program Mesquite (Maddison and Maddison 2011). Node 1 = Late Eocene (~35 million years ago, mya); Node 2 = 9.71 mya; Node 3 = 4.42 mya; and Node 4 = 3.02 mya (see Table 1). See text for details of the analysis.

Table 2. Morphological characters used for the character mapping analysis (see Table 1, Fig. 6). See text for details.

Character	State	Designation
Tail length	41–55% of snout-to-vent length	A0
	≥ 65% of snout-to-vent length	A1
Number of caudal vertebrae	25–28	B0
	40	B1
Number of transverse rows of ventromedial caudal scales (vent to tail tip) greater than 62	absent	C0
	present	C1
Usually one pair of enlarged preanal scales	present	D0
	absent	D1
First pair of infralabials usually in contact with chin shields	present	E0
	absent	E1
Number of maxillary teeth	8–9	F0
	6–7	F1
Upper posterior process of splenial bone	overlaps inner surface of coronoid	G0
	does not overlap coronoid	G1
Number of black tail bands (including black terminus on tail of juveniles)	4–5	H0
	6–7	H1
Adult total length	< 570 mm	I0
	> 600 mm	I1
Tongue color	black or nearly so	J0
	pink	J1
Supranasal-postnasal association	in contact	K0
	separated by first canthal	K1
Association of second supralabial and prenasal/nasal plates	in contact	L0
	separated by lorilabial	L1
Shape of mental scute	shield-shaped (elongate and triangular)	M0
	wedge-shaped (twice as long as wide)	M1
Dominant adult dorsal coloration	orange, pink	N0
	black or dark brown	N1
	yellow	N2
Adult dorsal yellow spotting	absent	O0
	extremely low	O1
	low	O2
	med	O3
	high	O4
Mental scute	scalloped edges absent	P0
	moderately scalloped edges	P1
Enlarged preanal scutes in some females	absent	Q0
	present	Q1
Ontogenetic melanism	absent	R0
	present	R1
Spots on tail in adults	absent	S0
	present	S1
Bands on tail	black	T0
	yellow	T1
	absent	T2

4. Character mapping analysis

A character mapping analysis (CMA) is one of several robust tools used in comparative biology to comprehend the distribution of traits (e.g., morphology), often by explicitly utilizing molecular phylogenetic information (Brooks and McLennan 1991; Harvey and Pagel 1991; Martins 1996; Freeman and Herron 2004; Maddison and Maddison 2011; for a critique, see Assis and Rieppel 2011). Specifically, the CMA aims to provide insights to the origin, frequency, and distribution of selected traits formally expressed onto a tree (e.g., Schuett et al. 2001, 2009; Fenwick et al. 2011). These procedures also are potentially useful in disentangling homology from homoplasy (Freeman and Herron 2004). Furthermore, the CMA provides a framework for testing hypotheses of adaptive evolution and the identification of species (Harvey and Pagel 1991; Futuyma 1998; Freeman and Herron 2004; Schuett et al. 2001, 2009; Maddison and Maddison 2011). However, CMA does not replace a strict phylogenetic analysis of morphological traits (Assis and Rieppel 2011).

Here, we used character mapping to investigate the morphological traits of the four subspecies of *H. horridum*, to gain insights on the distribution, divergence, and homology (e.g., shared-derived traits, such as possible autapomorphies) of these traits.

Methods.—We used published morphological data on *Heloderma* (Bogert and Martín del Campo 1956; Campbell and Vannini 1988; Campbell and Lamar 2004; Beck 2005) and selected 20 morphological characters for the CMA (Table 2). All characters were coded as binary (i.e., 0, 1) or multi-state (e.g., 0, 1, 2). Non-discrete multi-state characters (e.g., color pattern) were ordered from lowest to highest values. Character polarity was established by using *H. suspectum* as the outgroup. The CMA traced each character independently by using the outgroup analysis and parsimony procedures in Mesquite (Maddison and Maddison 2011), and we combined the individual results onto a global tree.

Results and discussion.—The CMA results (Fig. 6) show that multiple morphological traits are putative apomorphies or autapomorphies (traits unique to a single taxon) for the various *H. horridum* clades (subspecies) delimited in the molecular tree recovered by Douglas et al. (2010). Although we had a priori knowledge of specific and unique traits (presumptive autapomorphies) used to diagnose each of the subspecies, the CMA presents them in a phylogenetic and temporal framework. Our results show trends in scutellation (e.g., presence-absence, relative positions), relative tail length, and body color pattern, including ontogenetic melanism. Are the characters we used in the CMA stable in the subspecies? That question remains for future investigation; however, we have no evidence to the contrary. Indeed, we anticipate that these characters, and others likely to be revealed through detailed studies, will exhibit stability.

Importantly, each of these traits is amenable to further investigation and formal tests. For examples, what is the evolutionary and ecological significance of tongue color differences in beaded lizards (always pink) and Gila monsters (always black), the extreme differences in adult dorsal color pattern in *H. h. exasperatum* (yellow is predominant) vs. *H. h. alvarezi* (dark brown and patternless predominate), and ontogenetic melanism in *H. h. alvarezi*? As we discussed, beaded lizards occupy similar seasonally dry tropical forests, yet each of the subspecies exhibits pronounced molecular and morphological differentiation.

Similar types of questions concerning adaptation have used a CMA to explore social systems and sexual dimorphisms in lizards (Carothers 1984), male fighting and prey subjugation in snakes (Schuett et al. 2001), types of bipedalism in varanoids (Schuett et al. 2009), and direction of mode of parity (oviparous vs. viviparous) in viperids (Fenwick et al. 2011).

Subspecies and the Taxonomy of Beaded Lizards

Introduced in the late 19th century by ornithologists to describe geographic variation in avian species, the concept of subspecies and trinomial taxonomy exploded onto the scene in the early 20th century (Bogert et al. 1943), but not without controversy. The use of subspecies has been both exalted and condemned by biologists (see perspectives by Mallet 1995; Douglas et al. 2002; Zink 2004; Fitzpatrick 2010). Thousands of papers have been published in an attempt to either bolster the utility and promulgation of subspecies, or to denounce the concept as meaningless and misleading in evolutionary theory (Wilson and Brown 1953; Zink 2004). What is the problem? One common critical response is that the subspecies concept lacks coherence in meaning, and hence is difficult to comprehend (Futuyma 1998; Zink 2004). Moreover, the use of subspecies often masks real diversity (cryptic species, convergence) or depicts diversity that is non-existent or only trivial (e.g., lack of support in DNA-based analyses; Zink 2004). Indeed, as John Fitzpatrick attests (2010, p. 54), “The trinomial system cannot accurately represent the kind of information now available about genetic and character variation across space. Instead, even more accurate tools are being perfected for quantitative, standardized descriptions of variation. These analyses—not subspecies classifications—will keep providing new scientific insights into geographic variation.”

Even with the identification of a variety of problems, many authors recommend that complete abandonment of the trinomial category in taxonomy is not necessary nor advised (e.g., Mallett 1995, Hawlitschek et al. 2012). Unfortunately, a consensus among biologists concerning the use of subspecies is not likely to emerge (Fitzpatrick 2010). In step with Fitzpatrick’s (2010) comments, we

contend that the plethora of variation detected in organisms must be approached in a modern sense that does not rely upon a cumbersome and outdated taxonomic system. Indeed, we anticipate that the description of geographic variation in organisms, once emancipated from infraspecific taxonomy, will actually accelerate our understanding of variation and its complexities. In our view, the confusion in recognizing subspecies can also mislead conservation planning, and it has on more than one occasion (e.g., the dusky seaside sparrow, see Avise and Nelson 1989). We thus agree with Wilson and Brown (1953), Douglas et al. (2002), Zink (2004), Fitzpatrick (2010) and others in their insightful criticisms leveled at the subspecies concept and the use of trinomials in taxonomy. Other authors have echoed similar views (Burbrink et al., 2000; Burbrink 2001; Douglas et al. 2007; Tobias et al. 2010; Braby et al. 2011; Hoisington-Lopez 2012; Porras et al. 2013).

Given our reassessment of molecular (mt- and nDNAs), phylogeographic, morphological, and biogeographic evidence, we elevate the subspecies of *Heloderma horridum* to the rank of full species (Wiley, 1978; Zink 2004; Tobias et al. 2010; Braby et al. 2011; Porras et al. 2013). Indeed, Douglas et al. (2010, p. 164) stated that, "... unlike *H. suspectum*, our analyses support the subspecific designations within *H. horridum*. However, these particular lineages almost certainly circumscribe more than a single species ... Thus, one benefit of a conservation phylogenetic perspective is that it can properly identify biodiversity to its correct (and thus manageable) taxonomic level." Accordingly, based on multiples lines of concordant evidence, we recognize four species of beaded lizards. They are:

Mexican beaded lizard: *Heloderma horridum* (Wiegmann 1829)

Río Fuerte beaded lizard: *Heloderma exasperatum* (Bogert and Martín del Campo 1956)

Chiapan beaded lizard: *Heloderma alvarezi* (Bogert and Martín del Campo 1956)

Guatemalan beaded lizard: *Heloderma charlesbogerti* (Campbell and Vannini, 1988)

In the above arrangement, we do not recognize subspecies and vernacular names remain unchanged. The geographic distribution of the four species of beaded lizards is presented in Fig. 7. Locality data for the map were derived from Bogert and Martín del Campo (1956), Campbell and Vannini (1988), Schwalbe and Lowe (2000), Lemos-Espinal et al. (2003), Campbell and Lamar (2004), Beck (2005), Monroy-Vilchis et al. (2005), Ariano-Sánchez and Salazar (2007), Anzueto and Campbell (2010), Domiguez-Vega et al. (2012), and Sánchez-De La Vega et al. (2012). The "?" on the map (coastal Oaxaca, municipality: San Pedro Tututepec) denotes a jet-black adult specimen photographed by Vicente Mata-Silva (pers. comm.) in December 2010. The validity of

this record is questionable owing to its striking coloration resemblance to *H. alvarezi* from the Central Depression (Río Grijalva Depression) of Chiapas and extreme western Guatemala, rather than to *H. horridum*. Although the individual might represent an isolated population of *H. alvarezi*, further study in this area of Oaxaca is required to rule out human activity as an agent (e.g., displacement).

Beaded Lizards and Seasonally Dry Tropical Forests

The key to understanding the evolution and biogeography of beaded lizards and the prospects for implementing meaningful conservation measures is through a recognition of the biomes they occupy, which we emphasize are the widely but patchily distributed low elevation seasonally dry tropical forests (SDTFs; see Trejo and Dirzo 2000; Campbell and Lamar 2004; Beck 2005; Ariano-Sánchez 2006; Miles et al. 2006; Pennington et al. 2006; Dirzo et al. 2011; Domiguez-Vega et al. 2012).

The evolution of SDTFs in Mesoamerica is a complex evolutionary scenario (Stuart 1954, 1966), and our understanding of their origin and temporal diversification is in its infancy (Janzen, 1988; Becerra 2005; Pennington et al. 2006; Dirzo et al. 2011; De-Nova et al. 2012). One approach to grapple with complex issues such as the origin and historical construction of SDTFs in Mesoamerica has been to examine a single but highly diverse plant taxon within a phylogenetic (phylogenomic) backdrop. This approach, accomplished by Becerra (2005) and more recently by De-Nova et al. (2012), uses the woody plant (tree) *Bursera* (Burseraceae, Sapindales), a highly diverse genus (> 100 species) with a distribution in the New World and emblematic of most dry forest landscapes (De-Nova et al. 2012). Owing to this diversity, coupled with extensive endemism, this taxon has yielded valuable information that serves as a reasonable proxy for diversification and expansion of the SDTF biomes (Dick and Pennington 2012). Hence, plant (angiosperm) species richness and expansion of SDTF biomes in Mesoamerica is hypothesized to parallel the diversification of *Bursera* (Dick and Wright 2005).

Based on both plastid and nuclear genomic markers that were analyzed using fossil-calibrated techniques and ancestral habitat reconstruction, the origin of *Bursera* in Mesoamerica is hypothesized to be in northwestern Mexico in the earliest Eocene (~50 mya), with subsequent extensive diversification and southern expansion along the Mexican Transvolcanic Belt in the Miocene, especially ~7–10 mya (De-Nova et al. 2012). Accelerated clade diversification of *Bursera* and its sister genus *Commiphora* occurred during the Miocene, a period of increased aridity likely derived from seasonal cooling and rain shadow effects (Dick and Wright 2005). Although causal connections are complex, they include global tectonic pro-

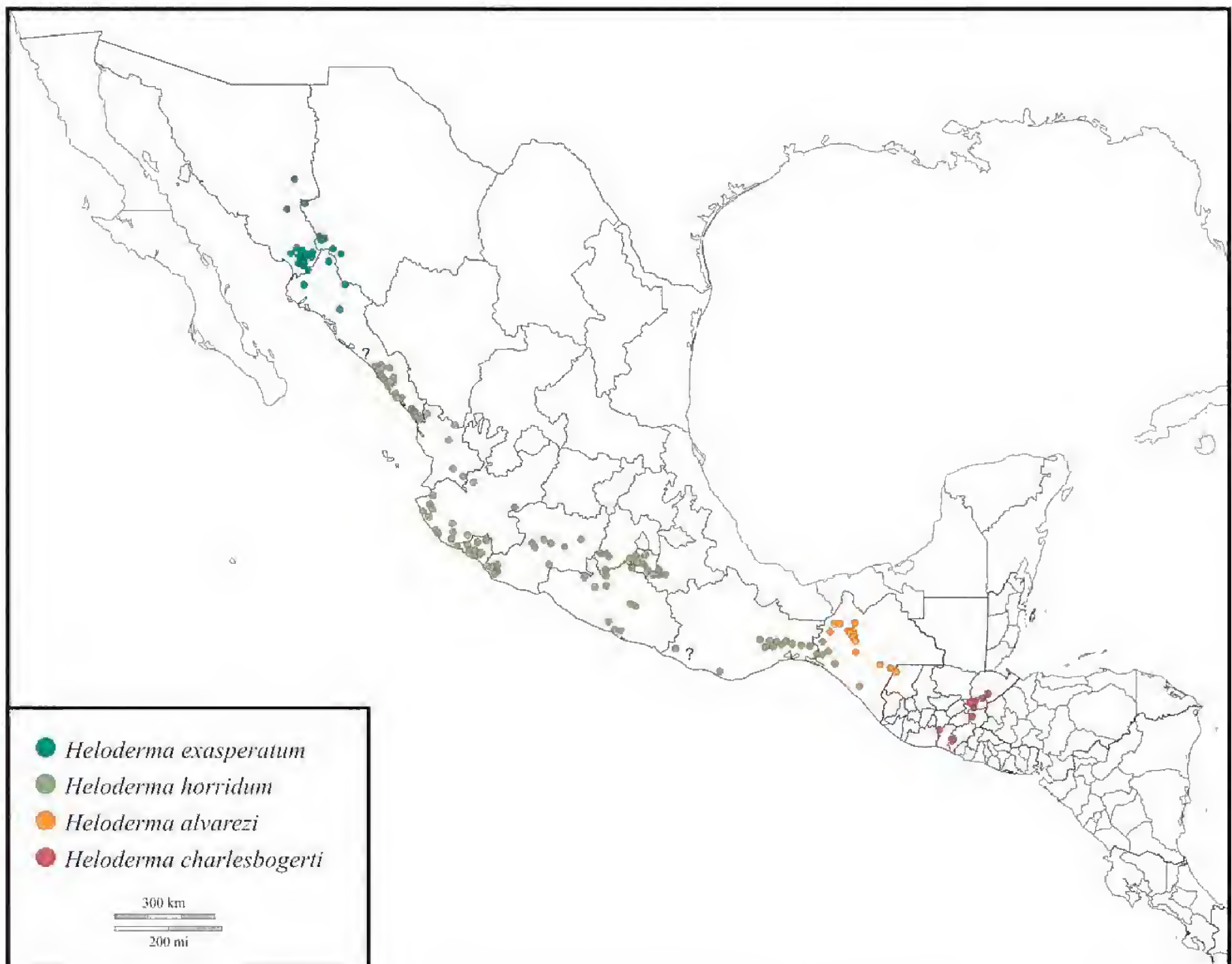


Fig. 7. The distribution of beaded lizards in Mexico and Guatemala. Colored dots represent verified sightings (populations) and museum records. Note the fragmented populations of all four species, which closely approximates the patchy distribution of seasonal dry tropical forests (see map in Brown and Lowe [1980]). See text for explanation of question marks (“?”) and other details.

cesses, orogenic activities (uplifting of the Sierra Madre Occidental and Sierra Madre Oriental) and local volcanism (Dick and Wright 2005; De-Nova et al. 2012). De-Nova et al. (2012) concluded by emphasizing that their phylogenomic analysis of *Bursera* points to high species diversity of SDTFs in Mesoamerica that derives from within-habitat speciation rates that occurred in the envelope of increasing aridity from the early Miocene to the present. Furthermore, they stated (p. 285), “This scenario agrees with previous suggestions that [angiosperm] lineages mostly restricted to dry environments in Mexico resulted from long periods of isolated evolution rather than rapid species generation....”

Beaded Lizard Evolution and Diversification

The phylogenetic analyses of *Heloderma horridum* (sensu lato) by Douglas et al (2010) provided fossil-calibrated estimates of divergence times, which allow us to draw connections to the origin and diversification of SDTFs in Mesoamerica (Table 1, Fig. 6). Based on those analyses, *H. horridum* (sensu lato) and *H. suspectum* are

hypothesized to have diverged from a most-recent common ancestor in the late Eocene (~35 mya), which corresponds to the establishment of *Bursera* in northwestern Mexico. Subsequent diversification (cladogenesis) of the beaded lizards occurred during the late Miocene (9.71 mya), followed by a lengthy period of stasis of up to 5 my, with subsequent cladogenesis extending into the Pliocene and Pleistocene. Of particular interest is that this scenario approximately parallels the diversification and southern expansion of SDTFs (Dick and Wright 2005; De-Nova et al. 2012). Accordingly, based on the above discussion of SDTFs and phylogenetic analyses, we suggest that beaded lizard lineage diversification resulted from long periods of isolated (allopatric) evolution in SDTFs. Douglas et al. (2010) referred to the fragmented tropical dry forests of western Mexico as “engines” for diversification. The extralimital distribution of *H. exasperatum* and *H. horridum* into adjacent pine-oak woodland and thorn scrub biomes appears to be relatively uncommon (Schwalbe and Lowe 2000; Beck 2005; Monroy-Vilchis et al. 2005).

Conservation of Beaded Lizards

A primary aim of this paper is to provide a useful and accurate synthesis of information on the taxonomy of beaded lizards that will lead to informed decisions regarding their conservation (see Douglas et al., 2010). Until recently, *H. horridum* (sensu lato) was designated as Vulnerable on the World Conservation Union (IUCN) Red List. In 2007, that designation was changed to Least Concern based on more stringent criteria (Canseco-Marquez and Muñoz 2007; categories and criteria version 3.1). The 2007 IUCN Red List also determined that, “Additional research is needed into the taxonomic status, distribution and threats to this species” (Canseco-Marquez and Muñoz 2007). The critically endangered status of *H. h. charlesbogerti* (sensu lato) in Guatemala (Ariano-Sánchez 2006; Ariano-Sánchez and Salazar 2007) has not altered the current IUCN Red List designation of this taxon, because population trends of other beaded lizards in Mexico remain “unknown” (www.iucnredlist.org/search; see International Reptile Conservation Foundation, IRCF; www.ircf.org). As more information on the population status of the newly elevated beaded lizards becomes available, in view of their fragmented distributions and threats to their habitats, the IUCN likely will designate these taxa as Vulnerable or a higher threat category (see our EVS analysis below). For example, *H. exasperatum*, *H. alvarezii*, and *H. charlesbogerti* all occupy limited areas of SDTF (Beck 2005).

In Mexico, helodermatid lizards are listed as “threatened” (amenazadas) under the Mexican law (NOM-059-SEMARNAT-2010), legislation comparable to that in the United States Endangered Species Act. The threatened category from Mexican law coincides, in part, with the “Vulnerable” category of the IUCN Red List. This document defines “threatened” as species or populations that could become at risk of extinction in a short to medium period if negative factors continue to operate that reduce population sizes or alter habitats. *Heloderma h. charlesbogerti* (sensu lato) is listed on the Guatemalan Lista Roja (Red List) as “endangered,” with approximately 200–250 adult individuals remaining in under 26,000 ha of its natural habitat of SDTF and thorn scrub, (Ariano-Sánchez 2006).

Furthermore, *H. h. charlesbogerti* (sensu lato) is listed on CITES Appendix I, a designation that includes species threatened with extinction (see CITES document appended to Ariano-Sánchez and Salazar 2007). Trade in CITES Appendix I species is prohibited except under exceptional circumstances, such as for scientific research (CITES 2007). The remaining taxa of *Heloderma horridum* (sensu lato) (*H. h. alvarezii*, *H. h. exasperatum*, and *H. h. horridum*) are listed on Appendix II of CITES (CITES 2007). International trade in Appendix II species might be authorized under an export permit, issued by the originating country only if conditions are met that show trade will not be detrimental to the survival of the

species in the wild. The United States Fish & Wildlife Service issues permits only if documentation is provided proving legal origin, including a complete paper trail back to legal founder animals. This procedure allows the importation of beaded lizards into the United States to be tightly regulated (in theory), and also subjects such imports to provisions of the Lacey Act that control commerce in illegally obtained fish and wildlife (Beck 2005).

Beaded Lizards: Denizens of Endangered SDTFs

Although occasional sightings of beaded lizards have been reported from mid elevation pine-oak woodlands, all four species primarily inhabit lowland SDTFs and rarely in associated thorn scrub, in both Mexico and Guatemala (Schwalbe and Lowe 2000; Lemos-Espinal et al. 2003; Campbell and Lamar 2004; Beck 2005; Monroy-Vilchis et al. 2005; Ariano and Salazar 2007; Domiguez-Vega et al. 2012). Thus, the optimal measure to reduce threats to beaded lizards is to maintain the integrity of their tropical dry forest habitats. Current threats to beaded lizards throughout their range include habitat loss, road mortality, poaching, and illegal trade (Beck 2005; Miles et al. 2006; Golicher et al. 2012). Habitat loss takes many forms, from the conversion of SDTFs to areas of agriculture and cattle ranching, to forest fragmentation owing to roads and other forms of development (Pennington et al. 2006). Degradation from human-introduced invasive (exotic) organisms and fire also are contributing factors (Beck 2005).

When the Spaniards arrived in the Western Hemisphere, Mesoamerican SDTFs covered a region stretching from Sonora (Mexico) to Panama, an area roughly the size of France (~550,000 km²). Today, only 0.1% of that region (under 500 km²) has official conservation status, and less than 2% remains sufficiently intact to attract the attention of conservationists (Janzen 1988; Hoekstra et al. 2005). Of all 13 terrestrial biomes analyzed by Hoekstra et al. (2005), the SDTF biome has the third highest conservation risk index (ratio of % land area converted per % land area protected), far above tropical wet forest and temperate forest biomes (Miles et al. 2006).

Mexico ranks among the most species rich countries in the world (García 2006; Urbina-Cardona and Flores-Villela 2010; Wilson and Johnson 2010; Wilson et al. 2010, 2013). Nearly one-third of all the Mexican herpetofaunal species are found in SDTFs (García 2006; DeNova et al. 2012). Neotropical dry forests span over 16 degrees of latitude in Mexico, giving way to variation in climatic and topography that results in a diversity of tropical dry forest types, and a concurrent high proportion of endemism of flora and fauna (García 2006; DeNova et al. 2012; Wilson et al. 2010; 2013). Mexican seasonally tropical dry forest, classified into seven ecoregions that encompass about 250,000 km², has enormous conservation value and has been identified as a hotspot

for conservation priorities (Myers et al. 2000; Sánchez-Azofeifa et al. 2005; García 2006; Urbina-Cardona and Flores-Villela, 2010; Wilson et al. 2010; Mittermeier et al. 2011). The vast majority (98%) of this region, however, lies outside of federally protected areas (De-Nova et al. 2012). With few exceptions, most of the protected areas in Mexico occur in the states of Chiapas and Jalisco, leaving much of the region (e.g., Nayarit and Sinaloa) without government (federal) protection (García 2006).

In Guatemala, less than 10% of an estimated 200,000 ha of original suitable habitat have been established as protected critical habitat in the Motagua Valley for the endangered *H. charlesbogerti* (Nájera Acevedo 2006). A strong effort led by local citizens, conservation workers, biologists, government officials, NGOs, and conservation organizations (e.g., The Nature Conservancy, International Reptile Conservation Association, Zoo Atlanta, and Zootropic) negotiated to have *H. h. charlesbogerti* (sensu lato) placed on CITES Appendix I, to purchase habitat, conduct research, employ local villagers in monitoring the lizards, and promote environmental education (Lock 2009). Similar efforts for beaded lizards have been underway for many years in Chiapas (Mexico), spearheaded at ZooMAT (Ramírez-Velázquez 2009), and in Chamela, Jalisco (www.ibiologia.unam.mx/ebchamela/www/reserva.html). Such efforts will need to expand in the years ahead and will doubtless play a crucial role if we hope to retain the integrity of existing SDTFs inhabited by beaded lizards throughout their range.

Discussion

In this paper, we reassessed the taxonomy of *Heloderma horridum* (sensu lato) using both published information and new analyses (e.g., CMA). We concluded that diversity in beaded lizards is greater than explained by infraspecific differences and that the recognition of subspecies is not warranted, as it obscures diversity. Our decision to elevate the four subspecies of *H. horridum* to full species status is not entirely novel (Beck 2005; Douglas et al. 2010). Furthermore, our taxonomic changes are based on integrative information (i.e., morphology, mt- and nDNA sequence information, biogeography) and changing perspectives on the utility of formally recognizing infraspecific diversity using a trinomial taxonomy (Wilson and Brown 1953; Douglas et al. 2002; Zink 2004; Porras et al. 2013). This decision not only adds to a better understanding of the evolution of helodermatids, but also provides an important evolutionary framework from which to judge conservation decisions with prudence (Douglas et al. 2002).

Below, we delineate and discuss prospective research and conservation recommendations for beaded lizards based on our present review. Borrowing some of the guidelines and recommendations for future research and conservation for cantils, also inhabitants of SDTFs, by Porras et al. (2013), we outline similar ones for the four

species of beaded lizards (*H. alvarezi*, *H. charlesbogerti*, *H. exasperatum*, and *H. horridum*).

Future Research and Conservation Recommendations

1. Throughout this paper we emphasized the importance of SDTFs in the distribution of beaded lizards, yet most SDTFs within their distribution are not Protected Natural Areas (PNAs; Beck 2005; Urbina-Cardona and Flores-Villela 2009; Domínguez-Vega et al. 2012). Accordingly, emphasis should be placed on those areas of SDTFs for prospective research, new conservation projects, and for establishing new PNAs. The protection of beaded lizards must be placed into a larger context of conservation planning. Proper stewardship of SDTFs and other biomes must include meaningful (scientific) protective measures for all of the flora and fauna, rather than piecemeal (e.g., taxon-by-taxon) approaches that lack a cohesive conservation plan (Douglas et al. 2010).

We applaud the efforts of Domínguez-Vega et al. (2012) in identifying conservation areas for beaded lizards; however, we do not agree with all of their conclusions. In particular, based on field experiences by one of us (DDB), we contend that the potential (predicted) range of *H. exasperatum* in Sonora (Mexico) based on the results of their habitat suitability modeling, appears exaggerated and thus may be misleading. In our opinion, their distribution maps (figs. 2 and 3) overestimate the extent of true SDTFs in Sonora, showing their occurrence in a type of biome that is more accurately classified as Sinaloan Thorn Scrub (see the excellent maps in Brown and Lowe 1980; Robichaux and Yetman 2000). In Sonora, beaded lizards (*H. exasperatum*) are rarely found in association with pure thorn scrub, while Gila monsters, in contrast, are frequently encountered in that type of habitat (Schwalbe and Lowe 2000; Beck 2005).

2. With few exceptions, the population viability of beaded lizards is largely unknown (Beck 2005; Ariano-Sánchez 2006; Ariano-Sánchez et al. 2007; Domínguez-Vega et al. 2012). We highly recommend that modern assessments of the four species occur at or near localities where they have been recorded (e.g., Jiménez-Valverde and Lobo 2007). Whereas *H. charlesbogerti*, and to a lesser degree *H. alvarezi* (Ramírez-Velázquez 2009), are receiving international conservation attention, we feel that similar consideration is necessary for *H. exasperatum* owing to its relatively limited geographic range (Sonora, Chihuahua, Sinaloa), the large extent of habitat destruction and fragmentation (Fig. 8), and limited areas receiving protection (Trejo and Dirzo 2000; Domínguez-Vega et al. 2012; see <http://www.conanp.gob.mx/regionales/>). In 1996, about 92,000 hectares in the Sierra de Álamos and the upper drainage of the Río Cuchujaqui were declared a biosphere reserve by the Secretary of the Environment and Natural Resources (SEMARNAT 2010), called the

Área de Protección de Fauna y Flora Sierra de Álamos y Río Cuchujaqui (Martin and Yetman 2000; S. Meyer, pers. comm.). Efforts continue in Sonora to set aside additional habitat for conservation, but, other than Álamos, no other areas with true SDTFs presently exist (Robichaux and Yetman 2000; S. Meyer, pers. comm.).

3. Conservation management plans for each of the species of beaded lizards should be developed from an integrative perspective based on modern population assessments, genetic information, and ecological (e.g., soil, precipitation, temperature) and behavioral data (e.g., social structure, mating systems, home range size).

Such a conservation plan is in place for the Guatemalan beaded lizard (*H. charlesbogerti*) by CONAP-Zootropic (www.ircf.org/downloads/PCHELODERMA-2Web.pdf). Also, aspects of burgeoning human population growth must be considered, since outside of PNAs these large slow-moving lizards generally are slaughtered on sight, killed on roads by vehicles (Fig. 9), and threatened by persistent habitat destruction primarily for agriculture and cattle ranching (Fig. 10). For discussions on conservation measures in helodermatid lizards, see Sullivan et al. (2004), Beck (2005), Kwiatkowski et al. (2008), Douglas et al. (2010), Domínguez-Vega et al. (2012), and Ariano-Sánchez and Salazar (2013).

In Mexico, the IUCN lists *Heloderma horridum* (sensu lato) under the category of Least Concern. Recently, Wilson et al. (2013) reported the Environmental Vulnerability Score (EVS) for *H. horridum* (sensu lato) as 11. Briefly, an EVS analysis assesses the potential threat status of a given species based on multiple criteria and provides a single score or index value (Wilson and McCranie 2004; Porras et al. 2013; Wilson et al. 2013). High EVS scores (e.g., 17), for example, signify vulnerability. With the taxonomic changes we proposed for beaded lizards, an EVS assessment is thus required for each species. Using the new criteria developed by Wilson et al. (2013; see Porras et al. 2013), we recalculated the EVS for the species of beaded lizards, which are presented below:

H. horridum: $5 + 4 + 5 = 14$

H. exasperatum: $5 + 7 + 5 = 17$

H. alvarezi: $4 + 6 + 5 = 15$

H. charlesbogerti: $4 + 8 + 5 = 17$

These recalculated values fall into the high vulnerability category (Wilson et al. 2013; Porras et al. 2013), underscoring the urgency for the development of conservation management plans and long-term population monitoring of all species of beaded lizards. These values thus need to be reported to the appropriate IUCN committees, so immediate changes in status can be made and conservation actions implemented.



Fig. 8. Destruction of seasonally dry tropical forest near Álamos, Sonora, Mexico. Photo by Daniel D. Beck.

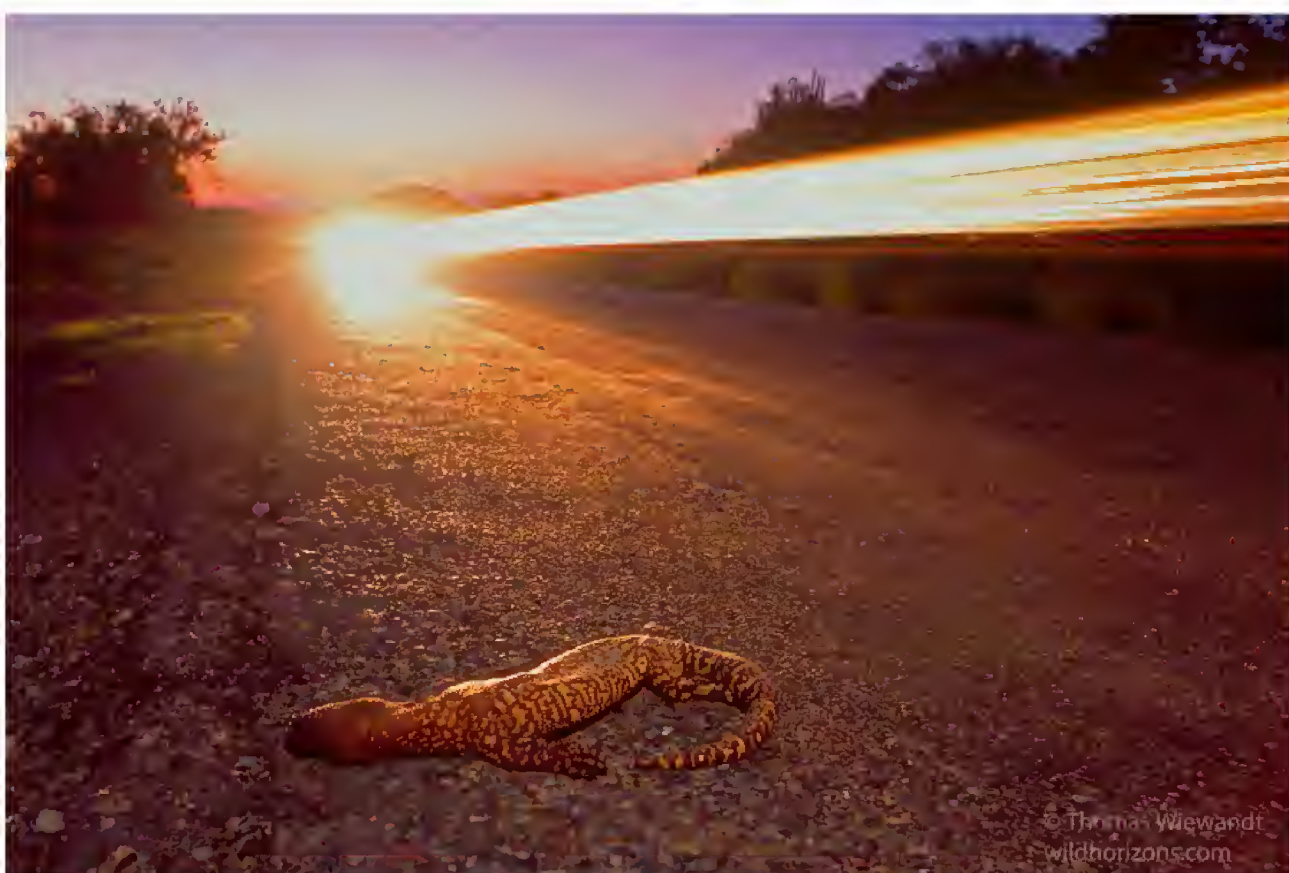


Fig. 9. A dead-on-the-road (DOR) *H. exasperatum* (sensu stricto) near Álamos, Sonora, Mexico. Vehicles on paved roads are an increasing threat to beaded lizards, Gila monsters, and other wildlife. Photo by Thomas Wiewandt.



Fig. 10. Agave cultivation in Mexico results in the destruction of seasonally dry tropical forests. *Photo by Thomas Wiewandt.*



Fig. 11. Antonio Ramirez Ramírez-Velázquez, a herpetologist, discusses the beauty and importance of beaded lizards (*H. alvarezii*, sensu stricto) to a group of enthusiastic children and their teacher at Zoo Miguel Álvarez del Toro (ZooMAT) in Tuxtla Gutiérrez, Chiapas, Mexico. The zoo was named in honor of its founding director, Señor Miguel Alvarez del Toro, who had a keen academic and conservation interest in beaded lizards. He collected the type specimen of *H. alvarezii* (described in Bogert and Martín del Campo, 1956), which was named in his honor. ZooMAT offers hands-on environmental education programs to schoolchildren and other citizens of southern Mexico. *Photo by Thomas Wiewandt.*

4. We recommend the establishment of zoo conservation (AZA) educational outreach programs, both ex situ and in situ, such as those currently in progress for *H. charlesbogerti* (www.IRCF.org; www.zooatlanta.org) and for *H. alvarezii* in Chiapas (Ramírez-Velázquez, 2009, see Fig. 11). Because of its limited range, destruction of its

natural habitat, small population size (200–250 adults) and endangered status, *H. charlesbogerti* is currently listed as CITES Appendix I (Ariano-Sánchez and Salazar 2007). Given the taxonomic elevation of these taxa, conservation agencies can use these charismatic lizards as flagship species in efforts to publicize conservation efforts in their respective countries at all levels of interest and concern, including education and ecotourism (Beck 2005). Eli Lilly Co., Disney Worldwide Conservation Fund and The Nature Conservancy support the conservation of *H. charlesbogerti* (Ariano-Sánchez and Salazar 2012). Such corporate involvement provides funds and positive public exposure (e.g., social network advertising) that otherwise would not be possible.

5. One of the major conclusions of this paper is that our knowledge of the taxonomy and phylogeography of beaded lizards remains at an elementary level. As discussed, a robust phylogeographic analysis using morphological characters is not available. Our character mapping exercise, for various reasons, is not a substitute procedure for detailed phylogenetic analyses using morphology (Assis 2009; Assis and Rieppel 2011). Other authors have made similar pleas concerning the importance of morphology, including fossils, in phylogenetic reconstruction (Poe and Wiens 2000; Wiens 2004, 2008; Gauthier et al. 2012). Moreover, further studies on the historical biogeography of helodermatids (e.g., ancestral area reconstruction) are needed (e.g., Ronquist 1997, 2001; Ree and Smith 2008). Detailed morpho-

logical analyses can be conducted with new tools such as computed tomography (CT) scans of osteological characters of both extant and fossil specimens (Gauthier et al. 2012), and geometric morphometric approaches to external characters (Davis 2012). Furthermore, in the expanding field of “venomics” new venom characters in beaded

lizards will likely be discovered, which might prove useful in phylogenetic analyses (Fry et al. 2009, 2010).

As we progress into the “Age of Genomics” with ever-growing computational advancements (e.g., bioinformatics; Horner et al. 2009), new and exciting methods to explore organismal diversity are opening, including such next-generation approaches as pyrosequencing (microsatellite isolation), establishing transcriptome databases, and whole-genome sequencing (Wiens 2008; Castoe et al. 2011; Culver et al. 2011). Currently, plans are underway to apply pyrosequencing methods to helodermatids to generate a nearly inexhaustible supply of microsatellite markers for a variety of proposed analyses (W. Booth and T. Castoe, pers. comm.). Standing on the shoulders of The Human Genome Project (Culver et al. 2011), and reaping the success of genome projects in other reptilian taxa (Castoe et al. 2011), it is now possible to establish a “Helodermatid Genome Project.” Beaded lizards and the Gila monster are especially good candidates for such an investment, especially given the importance of their venom components in medical research and recent pharmaceutical applications (Beck 2005; Douglas et al. 2010; Fry et al. 2009, 2010).

6. An important take-home message from Douglas et al. (2010) is that future conservation efforts will require a robust understanding of phylogenetic diversity (e.g., conservation phylogenetics) to make sensible (logical) and comprehensive conservation plans. For example, the range of *H. horridum* (sensu stricto) is the most expansive of the species of beaded lizards and has not been fully explored with respect to genetic diversity. Accordingly, sampling throughout its range may yield cryptic genetic diversity, perhaps even new species. We emphasize that viable conservation planning must incorporate all intellectual tools available, including those that incorporate old methods (e.g., paleoecological data) but viewed through a new lens (Douglas et al. 2007, 2009; Willis et al. 2010). Wisely, Greene (2005) reminds us that we are still grappling with understanding basic and essential issues concerning the natural history of most organisms. To that end, we must continue in our efforts to educate students and the public of the need for and importance of this branch of science.

7. The new taxonomic arrangement of beaded lizards we proposed will affect other fields of science, such as conservation biology and human medicine (Beck, 2005; Douglas et al., 2010). In Fry et al. (2010, p. 396, table 1), toxins are matched to the subspecies of beaded lizards and Gila monsters. Yet as noted by Beck (2005) and Douglas et al. (2010), the banded Gila monster (*H. s. cinctum*) is not a valid subspecies, which is based on several levels of analysis (i.e., morphology, geographic distribution, and haplotype data). Individuals assigned to

H. s. cinctum based on color and pattern, for example, have been found in southwestern Arizona near the Mexican border and in west-central New Mexico (Beck 2005). Furthermore, most venom researchers, including those who study helodermatids, often obtain samples from captive subjects in private collections and zoological institutions. Many of these animals have been bred in captivity and result from crossing individuals of unknown origin or from different populations (D. Boyer, pers. comm.). Among other negative outcomes, such “mutts” will confound results of the true variation of venoms. Geographic and ontogenetic variation in venom constituents is well established in other squamates (Minton and Weinstein 1986; Alape-Girón et al. 2008; Gibbs et al. 2009), which is apparently the case in helodermatids (Fry et al. 2010). Thus, we strongly encourage researchers investigating helodermatid venoms for molecular analysis and pharmaceutical development to use subjects with detailed locality information, as well as age, gender, and size, and to provide those data in their publications.

8. Owing to problems that many scientists, their students, and other interested parties from Mesoamerica have in gaining access to primary scientific literature, we highly recommend that authors seek Open Access peer-reviewed journals as venues for their publications on beaded lizards, an important factor in our choice for selecting the present journal (www.redlist-ARC.org) as a venue for our data and conservation message.

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Pseudoeurycea naucampatepetl. The Cofre de Perote salamander is endemic to the Sierra Madre Oriental of eastern Mexico. This relatively large salamander (reported to attain a total length of 150 mm) is recorded only from, “a narrow ridge extending east from Cofre de Perote and terminating [on] a small peak (Cerro Volcancillo) at the type locality,” in central Veracruz, at elevations from 2,500 to 3,000 m (Amphibian Species of the World website). *Pseudoeurycea naucampatepetl* has been assigned to the *P. bellii* complex of the *P. bellii* group (Raffaëlli 2007) and is considered most closely related to *P. gigantea*, a species endemic to the La Joya-Jalapa region of Veracruz and adjacent northeastern Hidalgo (Parra-Olea et al. 2001). This salamander is known from only five specimens and has not been seen for 20 years, despite thorough surveys in 2003 and 2004 (EDGE; www.edgeofexistence.org), and thus it might be extinct. The habitat at the type locality (pine-oak forest with abundant bunch grass) lies within Lower Montane Wet Forest (Wilson and Johnson 2010; IUCN Red List website [accessed 21 April 2013]). The known specimens were “found beneath the surface of roadside banks” (www.edgeofexistence.org) along the road to Las Lajas Microwave Station, 15 kilometers (by road) south of Highway 140 from Las Vigas, Veracruz (Amphibian Species of the World website). This species is terrestrial and presumed to reproduce by direct development.

Pseudoeurycea naucampatepetl is placed as number 89 in the top 100 Evolutionarily Distinct and Globally Endangered amphibians (EDGE; www.edgeofexistence.org). We calculated this animal’s EVS as 17, which is in the middle of the high vulnerability category (see text for explanation), and its IUCN status has been assessed as Critically Endangered. Of the 52 species in the genus *Pseudoeurycea*, all but four are endemic to Mexico (see Appendix of this paper and Acevedo et al. 2010). *Photo by James Hanken.*

A conservation reassessment of the amphibians of Mexico based on the EVS measure

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Abstract.—Global amphibian population decline is one of the better documented symptoms of biodiversity loss on our planet, and one of the environmental super-problems humans have created. Most people believe that we should manage nature for our benefit, instead of understanding that we are part of the natural world and depend on it for our survival. As a consequence, humans keep unraveling Earth's life-support systems, and to reverse this trend must begin to develop a sustainable existence. Given this reality, we examine the conservation status of the 378 species of amphibians in Mexico, by using the Environmental Vulnerability Score (EVS) algorithm. We summarize and critique the IUCN Red List Assessments for these creatures, calculate their EVS, and compare the results of both conservation assessments. We also compare the EVS for Mexican amphibians with those recently reported for Mexican reptiles, and conclude that both groups are highly imperiled, especially the salamanders, lizards, and turtles. The response of humans to these global imperatives has been lackluster, even though biological scientists worldwide have called attention to the grave prospects for the survival of life on our planet. As part of the global community, Mexico must realize the effects of these developments and the rapid, comprehensive need to conserve the country's hugely significant herpetofauna. Based on this objective, we provide five broad-based recommendations.

Key words. EVS, anurans, salamanders, caecilians, IUCN categorizations, survival prospects

Resumen.—La disminución global de las poblaciones de anfibios es uno de los síntomas más documentados sobre la pérdida de biodiversidad en nuestro planeta, que a su vez es uno de los super-problemas ambientales creados por los seres humanos. La mayoría de los seres humanos creemos que podemos y debemos manejar la naturaleza para nuestro propio beneficio, en lugar de comprender que somos parte y dependemos de ella misma. Como consecuencia de ello, estamos desarticulando los sistemas biológicos del planeta, y para revertir esta tendencia debemos desarrollar una existencia sostenible. Ante esta realidad, examinamos el estado de conservación de las 378 especies de anfibios mexicanos utilizando el algoritmo de Medida de Vulnerabilidad Ambiental (EVS). Resumimos y criticamos las evaluaciones de la Lista Roja para estos organismos, calculamos su EVS, y comparamos los resultados con los resultados de la categorización de la UICN. También comparamos el EVS de los anfibios mexicanos con los publicados recientemente para los reptiles de México, concluyendo que ambos grupos están en un peligro altamente significativo, principalmente las salamandras, las lagartijas y las tortugas. La respuesta humana a esta crisis global ha sido mediocre, a pesar de que la comunidad mundial de biólogos se une al llamado de atención sobre las perspectivas graves que amenazan la supervivencia de la vida en nuestro planeta. Como parte de la comunidad mundial, el país de México debe de considerar los efectos de estos cambios, y la rápida necesidad de conservar de manera integral la herpetofauna altamente significativa de este país. Basándonos en este objetivo, proporcionamos cinco recomendaciones generalizadas.

Palabras claves. EVS, anuros, salamandras, cecilios, categorización de UICN, perspectivas de supervivencia

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How will humans react to an increased awareness that Earth's biodiversity is diminishing? What are these losses telling us about our place on the planet, our role in the biosphere? What is our role in conserving biodiversity as we become custodians of a planet that has clear limitations? And how can we pass to future generations the wisdom needed to make sound environmental decisions? The answers to these questions will tell us much about ourselves, and science will take us only part of the way along that journey.

Collins and Crump 2009: 205.

Introduction

Global amphibian population decline is a well-known environmental issue to conservation biologists and herpetologists (Collins and Crump 2009; Stuart et al. 2010). This issue, however, often does not make it onto lists of the world's most significant problems. A survey of European Union citizens conducted in the fall of 2011 identified the following problems of greatest concern: (1) poverty, hunger and lack of drinking water (28% of those surveyed); (2) climate change (20%); (3) the economic situation (16%); (4) international terrorism (11%); (5) the availability of energy (7%); (6) the increasing global population (5%); (7) the spread of infectious disease (4%); (8) armed conflict (4%); the proliferation of nuclear weapons (3%); and (10) don't know (2%).

Such surveys expose several underlying concerns. One is that amphibian population decline is not on the list, but neither is the larger issue of biodiversity decline. Another concern is that this "pick the biggest problem" approach does not acknowledge that all of these issues are intertwined and capable of creating "environmental super-problems," as explained by Bright (2000). Further, with respect to the natural world Bright (2000: 37) indicated that "we will never understand it completely, it will not do our bidding for free, and we cannot put it back the way it was." These features are characteristic of biodiversity and biodiversity decline, and indicative of how little we know about the current status of biodiversity. Mora et al. (2011) provided an estimate of the total amount of biodiversity, which they indicated at approximately 8.7 million (± 1.3 million SE), with about 86% of the existing land species and 91% of the oceanic species still awaiting description. The description of new taxa is only the initial step toward understanding how the natural world works. The world will not do our bidding for free, since we cannot obtain an appreciable quantity of anything from nature without sacrificing something in the process. In transforming our planet to fill the needs of our species, we have destroyed the habitats of countless creatures (including amphibians) that also have evolved over time. We cannot reverse this damage, as evidenced by the fact that we have been unable to provide permanent solutions to any of the significant environmental problems. Such is

the case with biodiversity decline, since no retreat from species extinction is possible.

Biodiversity decline is an environmental super-problem, as contributing factors include habitat modification, fragmentation, and loss, pollution and disease, over-harvesting, exotic species, and extinction (Vitt and Caldwell 2009). These problems interact to enmesh species into an extinction vortex, defined as "a downward population spiral in which inbreeding and genetic drift combine to cause a small population to shrink and, unless the spiral is reversed, to become extinct" (Campbell et al. 2008: 1251). Theoretically, this effect should significantly impact species with narrower distributions.

The extent of biodiversity decline is unknown, although most estimates indicate that we know very little about this topic. With respect to animals, we know substantially more about the diversity of vertebrates than invertebrates. Among the vertebrates subjected to a global analysis, a greater proportion of amphibians have been documented as threatened than birds or mammals (Stuart et al. 2010). Reptiles and fishes, however, remain unassessed.

The data presented in Stuart et al. (2010) essentially were the same as in Stuart (2004). The number of amphibians known globally now exceeds 7,000 (7,139; www.amphibiaweb.org [accessed 8 June 2013]), which is 24.3% greater than the one cited by Stuart et al. (2010). The description of new species of amphibians obviously is a "growth industry," and the rate of discovery does not appear to be slowing. Thus, we expect that the number of new amphibian taxa from Mexico will continue to increase.

Another major fault with assessing the "world's greatest problems" is that their causes are not identified. As noted by Wilson et al. (2013: 23), "no permanent solution to the problem of biodiversity decline (including herpetofaunal decline) will be found in Mexico (or elsewhere in the world) until humans recognize overpopulation as the major cause of degradation and loss of humankind's fellow organisms." Further, they stated (Pp. 23–24) that, "solutions will not be available until humanity begins to realize the origin, nature, and consequences of the mismatch between human worldviews and how our planet functions." Miller and Spoolman (2012: 20) defined this "planetary management worldview" as maintaining that "we are separate from and in charge of nature, that nature exists mainly to meet our needs and increasing wants, and that we can use our ingenuity and technology to manage the earth's life-support systems, mostly for our benefit, into the distant future."

Unfortunately, over the span of about 10,000 years, humans have dismantled the planet's life-support systems, and today we are living unsustainably (Miller and Spoolman 2012). So, until and unless we develop an environmentally sustainable society, no lasting, workable solutions to environmental problems will be found, including that of biodiversity decline.



Incilius pisinnus. The Michoacán toad, a state endemic, is known only from the Tepalcatepec Depression. This toad's EVS has been assessed as 15, placing it in the lower portion of the high vulnerability category, and its IUCN status as Data Deficient. This individual came from Apatzingán. *Photo by Iván Trinidad Ahumada-Carrillo.*



Craugastor hobartsmithi. The distribution of the endemic Smith's pygmy robber frog is along the southwestern portion of the Mexican Plateau, from Nayarit and Jalisco to Michoacán and the state of México. Its EVS has been determined as 15, placing it in the lower portion of the high vulnerability category, and its IUCN status as Endangered. This individual is from the Sierra de Manantlán in Jalisco. *Photo by Iván Trinidad Ahumada-Carrillo.*

Nonetheless, building a sustainable society requires steps that only a few people appear willing to take. Thus, efforts by conservation biologists to reverse biodiversity decline, including amphibian population decline, must proceed with the realization that we will only be designing short-term solutions that deal with the symptoms of the problems rather than their causes. Within this realization, we undertake the following reassessment of the conservation status of the amphibians of Mexico.

A Revised Environmental Vulnerability Measure

In conducting a conservation reassessment of Mexican reptiles, Wilson et al. (2013) revised the Environmental Vulnerability Score (EVS) from that used in various chapters of Wilson et al. (2010). Similarly, we modified the EVS measure for use with Mexican amphibians, especially by substituting the human persecution scale used for reptiles with a reproductive mode scale, as did Wilson and McCranie (2004) and other authors who used this measure with Central American amphibians (see Wilson et al. 2010).

Wilson et al. (2013) indicated that the EVS measure originally was designed for use in cases where the details of the population status of a species, upon which many of the criteria for IUCN status categorization depend, were not available, as well as to provide an estimate of the susceptibility of amphibians and reptiles to future environmental threats. The advantages for using the EVS measure are indicated below (see EVS for Mexican amphibians).

The EVS algorithm we developed for use with Mexican amphibians consists of three scales, for which the values are added to produce the Environmental Vulnerability Score. The first scale deals with geographic distribution, as follows:

- 1 = distribution broadly represented both inside and outside Mexico (large portions of range are both inside and outside Mexico)
- 2 = distribution prevalent inside Mexico, but limited outside Mexico (most of range is inside Mexico)
- 3 = distribution limited inside Mexico, but prevalent outside Mexico (most of range is outside Mexico)
- 4 = distribution limited both inside and outside Mexico (most of range is marginal to areas near border of Mexico and the United States or Central America)
- 5 = distribution within Mexico only, but not restricted to vicinity of type locality
- 6 = distribution limited to Mexico in the vicinity of type locality

The second scale deals with ecological distribution, as follows:

- 1 = occurs in eight or more formations
- 2 = occurs in seven formations
- 3 = occurs in six formations
- 4 = occurs in five formations
- 5 = occurs in four formations
- 6 = occurs in three formations
- 7 = occurs in two formations
- 8 = occurs in one formation

The third scale is concerned with the type of reproductive mode, as follows:

- 1 = both eggs and tadpoles in large to small bodies of lentic or lotic water
- 2 = eggs in foam nests, tadpoles in small bodies of lentic or lotic water
- 3 = tadpoles occur in small bodies of lentic or lotic water, eggs outside of water
- 4 = eggs laid in moist situation on land or moist arboreal situations, direct development, or viviparous
- 5 = eggs and tadpoles in water-retaining arboreal bromeliads or water-filled tree cavities

Once these three components are added, their EVS can range from 3 to 19. Wilson and McCranie (2004) allocated the range of scores for Honduran amphibians into three categories of vulnerability to environmental degradation, as follows: low (3–9); medium (10–13); and high (14–19). We use the same categorization.

Recent Changes to the Mexican Amphibian Fauna

Our knowledge of the composition of the Mexican amphibian fauna keeps changing due to discovery of new species and the systematic adjustment of certain known species, which adds or subtracts from the list of taxa that appeared in Wilson et al. (2010). Since that time, the following seven species have been described or resurrected:

Incilius aurarius: Mendelson et al. 2012. *Journal of Herpetology* 46: 473–479. New species.

Incilius mccoysi: Santos-Barrera and Flores Villela. 2011. *Journal of Herpetology* 45: 211–215. New species.

Craugastor saltator: Hedges et al. 2008. *Zootaxa* 1737: 1–182. Resurrected from synonymy of *C. mexicanus*.



Eleutherodactylus modestus. The endemic blunt-toed chirping frog is known from Colima and southwestern Jalisco. Its EVS has been calculated at 16, placing it in the middle portion of the high vulnerability category, and its IUCN status as Vulnerable. This individual is from the Sierra de Manantlán in Jalisco. *Photo by Iván Trinidad Ahumada-Carrillo.*



Dendropsophus sartori. The endemic Taylor's yellow treefrog is distributed along the Pacific slopes from Jalisco to Oaxaca. Its EVS has been determined as 14, at the lower end of the high vulnerability category, and its IUCN status as of Least Concern. This individual came from the Municipality of Minatitlán, Colima. *Photo by Jacobo Reyes-Velasco.*

Charadrahyla tecuani: Campbell et al. 2009. *Copeia* 2009: 287–295. New species.

Gastrophryne mazatlanensis: Streicher et al. 2012. *Molecular Phylogenetics and Evolution* 64: 645–653. Resurrected from synonymy of *G. olivacea*.

Bolitoglossa chinanteca: Rovito et al. 2012. *ZooKeys* 185: 55–71. New species.

Pseudoeurycea cafetalera: Parra-Olea et al. 2010. *Zootaxa* 2725: 57–68. New species.

This represents an increase of 2.0% over the 373 species listed by Wilson and Johnson (2010).

The following species have undergone status changes, and include some taxa discussed in the addendum to Wilson and Johnson (2010):

Diaglena spatulata: Smith et al. 2007. *Evolution* 61: 2075–2085. Transfer from genus *Triprrion*.

Hypopachus ustus: Streicher et al. 2012. *Molecular Phylogenetics and Evolution* 64: 645–653. Transfer from genus *Gastrophryne*. Spelling of specific epithet corrected by Frost (2013).

Trachycephalus typhonius: Lavilla et al. 2010. *Zootaxa* 2671: 17–30. New name for *T. venulosus*.

Ixalotriton niger: Wake. 2012. *Zootaxa* 3484: 75–82. Resurrection of genus.

Ixalotriton parva: Wake. 2012. *Zootaxa* 3484: 75–82. Resurrection of genus.

IUCN Red List Assessment of Mexican Amphibians

The IUCN assessment of Mexican amphibians was conducted as part of a Mesoamerican Workshop held in 2002 at the La Selva Biological Station in Costa Rica (see foreword in Köhler 2011). The results of this workshop were incorporated into a general worldwide overview called the Global Amphibian Assessment (Stuart et al. 2004; Stuart et al. 2008; Stuart et al. 2010). This overview uncovered startling conclusions, of which the most important was that nearly one-third (32.3%) of the world’s amphibian species are threatened with extinction, i.e., were assessed as Critically Endangered, Endangered, or Vulnerable. This proportion did not include 35 species considered as Extinct or Extinct in the Wild, and by adding them 1,891 of 5,743 species (32.9%) were considered as

Table 1. IUCN Red List categorizations for Mexican amphibian families.

Families	Number of species	IUCN Red List categorizations						
		Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Bufonidae	35	1	7	2	3	19	1	2
Centrolenidae	1	—	—	—	—	1	—	—
Craugastoridae	39	7	8	7	3	6	6	2
Eleutherodactylidae	23	2	4	7	—	4	5	1
Hylidae	97	29	18	10	4	25	8	3
Leiuperidae	1	—	—	—	—	1	—	—
Leptodactylidae	2	—	—	—	—	2	—	—
Microhylidae	6	—	—	1	—	4	—	1
Ranidae	28	4	2	5	2	12	2	1
Rhinophrynidae	1	—	—	—	—	1	—	—
Scaphiopodidae	4	—	—	—	—	2	—	2
Subtotals	237	43	39	31	12	77	22	12
Ambystomatidae	18	9	2	—	—	2	3	2
Plethodontidae	118	36	37	11	9	10	12	3
Salamandridae	1	—	1	—	—	—	—	—
Sirenidae	2	—	—	—	—	2	—	—
Subtotals	139	45	40	11	9	14	15	5
Dermophiidae	2	—	—	1	—	—	1	—
Subtotals	2	—	—	1	—	—	1	—
Totals	378	88	79	44	21	91	38	17



Smilisca dentata. The endemic upland burrowing treefrog occurs only in southwestern Aguascalientes and adjacent northern Jalisco. Its EVS has been assessed as 14, placing it at the lower end of the high vulnerability category, and its IUCN status as Endangered. This individual was found in the Municipality of Ixtlahuacán del Río, Jalisco. *Photo by Jacobo Reyes-Velasco.*



Lithobates johnei. Moore's frog is an endemic anuran whose distribution is limited to southeastern San Luis Potosí, eastern Hidalgo, and northern Puebla. Its EVS has been assessed as 14, placing it at the lower end of the high vulnerability category, and its IUCN status as Endangered. This individual came from Río Claro, Municipality of Molango, Hidalgo. *Photo by Uriel Hernández-Salinas.*

threatened, near extinction, or extinct. Notably, another 1,290 species (22.5%) were evaluated as Data Deficient, i.e., too poorly known to allocate to any of the other IUCN categories. By adding these species to the previous figure of 1,891, an astonishing amount of amphibian species (3,181 [55.4%]) known at that time were considered threatened, near extinction, extinct, or too poorly known to assess. These horrific pronouncements gave rise to a worldwide cottage industry that continues to evaluate the state of amphibian population decline, as registered in a number of websites, most prominently AmphibiaWeb and the Global Amphibian Assessment.

The IUCN Red List website lists the current categorizations for the world’s amphibians using the standard IUCN system. We accessed this website in order to summarize the current situation for Mexican amphibians (Table 1). The data in this table are more complete than those for reptiles, as reported by Wilson et al. (2013). All but 17 of the current 378 known Mexican amphibian species have been assigned to an IUCN category, and as for the reptiles (see Wilson et al. 2013) we placed these 17 amphibian taxa (4.5%) in a Not Evaluated (NE) category. The remaining categorizations are: Critically Endangered

(CR; 88; 23.2%); Endangered (EN; 79; 20.8%); Vulnerable (VU; 44; 11.6%); Near Threatened (NT; 21; 5.5%); Least Concern (LC; 92; 24.2%); and Data Deficient (DD; 38; 10.0%). Thus, 211 species (55.7%) are placed in one of the three threat categories (CR, EN, or VU), a proportion significantly higher from that reported for these categories on a global scale (CR+EN+VU = 1,856 species, 32.3%; Stuart et al., 2010). If the DD species are added to those in the threat categories, then 249 (65.7%) are either threatened with extinction or too poorly known to allow for assessment, a proportion significantly beyond that for the global situation (CR+EN+VU+DD = 3,146 species; 54.8%; Stuart et al. 2010).

The largest proportion of threatened species are in the anuran families Craugastoridae (22 of 39 species; 56.4%), Eleutherodactylidae (13 of 24 species; 54.2%), and Hylidae (57 of 97 species; 58.8%), and the salamander families Ambystomatidae (11 of 19 species; 57.9%) and Plethodontidae (84 of 118 species; 71.2%). Collectively, the 297 species in these five families make up 78.4% of the amphibian taxa in Mexico, and the 187 threatened species in these families comprise 88.6% of the 211 total.

Table 2. Environmental Vulnerability Scores for Mexican amphibian species, arranged by family. Shaded area to left encompasses low vulnerability scores, and to the right high vulnerability scores.

Families	Number of species	Environmental Vulnerability Scores																
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Bufo	35	1	—	1	2	2	2	3	2	6	4	5	5	2	—	—	—	—
Centrolenidae	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Craugastoridae	39	—	—	—	—	—	1	1	1	1	1	4	4	10	3	5	8	—
Eleutherodactylidae	23	—	—	—	—	—	—	—	—	2	3	—	—	3	4	8	3	—
Hylidae	97	1	2	—	—	4	4	7	5	9	11	16	22	12	1	1	1	1
Leiuperidae	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Leptodactylidae	2	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Microhylidae	6	—	1	—	—	1	2	1	1	—	—	—	—	—	—	—	—	—
Ranidae	28	1	—	1	—	1	2	2	2	2	5	4	5	3	—	—	—	—
Rhinophrynidae	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Scaphiopodidae	4	1	—	—	1	—	—	—	1	—	1	—	—	—	—	—	—	—
Subtotals	237	4	3	3	4	9	12	14	13	20	25	29	36	30	8	14	12	1
Subtotals %	—	1.7	1.3	1.3	1.7	3.8	5.1	5.9	5.4	8.4	10.5	12.2	15.2	12.7	3.4	5.9	5.1	0.4
Ambystomatidae	18	—	—	—	—	—	—	—	2	—	—	4	5	7	—	—	—	—
Plethodontidae	118	—	—	—	—	—	—	1	—	2	3	3	8	16	13	36	36	—
Salamandridae	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Sirenidae	2	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Subtotals	139	—	—	—	—	—	—	1	2	2	6	7	13	23	13	36	36	—
Subtotals %	—	—	—	—	—	—	—	0.7	1.4	1.4	4.3	5.0	9.4	16.6	9.4	25.9	25.9	—
Dermophiidae	2	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—
Subtotals	2	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—
Subtotals %	—	—	—	—	—	—	—	—	—	50.0	50.0	—	—	—	—	—	—	—
Totals	378	4	3	3	4	9	12	15	15	23	32	36	49	53	21	50	48	1
Totals %	—	1.1	0.8	0.8	1.1	2.3	3.2	4.0	4.0	6.1	8.4	9.5	12.9	14.0	5.6	13.2	12.7	0.3



Triprion petasatus. The Yucatecan casque-headed treefrog is restricted primarily to the Yucatan Peninsula, occurring in the Mexican states of Yucatán, Campeche, and Quintana Roo, as well as in northern Guatemala and northern Belize. A disjunct population also has been recorded from Santa Elena, Departamento de Cortés, Honduras. Its EVS has been calculated as 10, placing it at the lower end of the medium vulnerability category, and its IUCN status is of Least Concern. Although this treefrog is broadly distributed in the Yucatan Peninsula, it usually is found only during the rainy season when males and females congregate around restricted bodies of water (solution pits, cenotes, and ephemeral ponds) on this flat limestone platform. During the dry season, these frogs retreat into tree holes and rock crevices, and sometimes use their head to plug the opening. This individual is from the state of Yucatán. *Photo by Ed Cassano.*

These data from the IUCN Red List show a frightening picture for the amphibian fauna of Mexico, acknowledged as a major herpetodiversity hotspot in the world on the basis of its diversity and endemism (Wilson and Johnson 2010). Mexico's level of amphibian endemism (66.8%) also has been reported as greater than that for the country's reptiles (57.2%; Wilson and Johnson 2010). Even more frightening is the fact that Mexican salamanders are more threatened than anurans (Table 1). Of the 139 recognized species of salamanders, 96 (69.1%) were assessed into one of the threat categories, as compared to anurans (114 of 236 [48.3%]). In addition, a much smaller proportion of salamander species were judged as Least Concern (14 [10.1%]), as compared to anurans (78 [33.1%]).

Critique of the IUCN Assessment

Although the conservation status of amphibians in Mexico is better understood than that for reptiles (see Wilson et al. 2013), a need for reassessment still is required for several reasons. About 10% of Mexico's amphibians have been judged as Data Deficient, and thus their conservation status remains undetermined. In addition, because certain species have been described recently (see above), 4.5% have not been evaluated (see www.iucnredlist.org; accessed 08 May 2013). Also, by adding the DD and NE species, 55 (14.5%) of Mexico's amphibians presently are not assigned to any of the other IUCN categories. Thus, we consider it worthwhile to subject the Mexican amphibians to the same assessment measure applied by Wilson et al. (2013) for reptiles, to allow for a comparison between these two groups. For these reasons, we will reassess the Mexican amphibian fauna using the Environmental Vulnerability Score (EVS).

EVS for Mexican Amphibians

The EVS provides several advantages for assessing the conservation status of amphibians and reptiles. First, this measure can be applied as soon as a species is named, because the information necessary for its application generally is known at that point. Second, calculating the EVS is economical because it does not require expensive, grant-supported workshops, such as those undertaken for the Global Amphibian Assessment (sponsored by the IUCN). Third, the EVS is predictive, as it measures susceptibility to anthropogenic pressure and can pinpoint taxa with the greatest need of immediate attention and continued scrutiny. Finally, it is simple to calculate and does not "penalize" poorly known species. Thus, given the geometric pace at which environmental threats worsen, since they are commensurate with the rate of human population growth, it is important to use a conservation assessment measure that can be applied simply, quickly, and economically.

We calculated the EVS using the above-mentioned methodology. This step allowed us to determine the conservation status of all the currently recognized Mexican amphibian species (378), including the 55 species placed in the DD category or not evaluated by the IUCN (www.iucnredlist.org; see Appendix 1, Table 2).

Theoretically, the EVS can range from 3 to 20 (in Mexico, from 3 to 19). A score of 3 is indicative of a species that ranges widely both within and outside of Mexico, occupies eight or more forest formations, and lays its eggs in small to large lentic or lotic bodies of water. Four such species (one each in the families Bufonidae, Hylidae, Ranidae, and Scaphiropodidae) are found in Mexico. At the other extreme, a score of 20 relates to a species that is known only from the vicinity of the type locality, occupies a single forest formation, and its eggs and tadpoles are found in water-retaining arboreal bromeliads or water-filled tree cavities (no such species occur in Mexico). Thus, all the scores fall within the range of 4–19.

In the Introduction, we expressed an interest in attempting to determine the impact of small populations on amphibian species survival in Mexico. The data in Appendix 1 allow us to approximate an answer to this question, inasmuch as one of the components of the EVS assesses the extent of geographic distribution on a sliding scale (1–6), on which higher numbers signify increasingly smaller geographic ranges. Using this range, the distribution of the 378 Mexican species is as follows: 1 = 13 species (3.4%); 2 = 20 (5.3%); 3 = 28 (7.4%); 4 = 64 (16.9%); 5 = 126 (33.3%); and 6 = 127 (33.6%). Obviously, the higher the value of the geographic range, the higher the number and percentage of the taxa involved. These figures indicate that about one-third of the amphibian species in Mexico are known only from the vicinity of their respective type localities. The range of another one-third is somewhat broader, but still limited to the confines of Mexico. As a consequence, the survival prospects of about two-thirds of Mexico's amphibians are tied to changes in their natural environment, as well as to the conservation atmosphere in this nation.

We summarized the EVS for Mexican amphibians by family in Table 2. The EVS range falls into the following three portions: low (3–9), medium (10–13), and high (14–19).

The range and average EVS for the major amphibian groups are as follows: anurans = 3–19 (12.4); salamanders = 9–18 (15.9); and caecilians = 11–12 (11.5). Salamanders generally are significantly more susceptible than anurans to environmental degradation and caecilians somewhat less susceptible than anurans (although only two caecilian species are involved). The average scores either fall in the medium category, in the case of anurans and caecilians, or in the middle portion of the high category, in the case of salamanders. The average EVS for all amphibian species is 13.7, a value near the lower end of the high range of vulnerability.



Ambystoma velasci. The endemic Plateau tiger salamander, as currently recognized, is distributed widely from northwestern Chihuahua southward along the eastern slopes of the Sierra Madre Oriental, and from southern Nuevo León in the Sierra Madre Oriental, westward to Zacatecas and southward onto the Transverse Volcanic Axis of central Mexico. Its EVS has been determined as 10, placing it at the lower end of the medium vulnerability category, and its IUCN status is of Least Concern. Even though this species does not appear threatened, this is likely an artifact of the composite nature of this taxon. This individual was found at Santa Cantarina, Hidalgo. *Photo by Raciél Cruz-Elizalde.*



Bolitoglossa franklini. Franklin's salamander is distributed along Pacific slopes from southern Chiapas, Mexico, southeastward to south-central Guatemala. Its EVS has been determined as 14, placing it at the lower end of the high vulnerability category, and its IUCN status as Endangered. This individual came from Cerro Mototal, in the Municipality of Motozintla, Chiapas. *Photo by Sean M. Rovito.*

An EVS of 14, at the lower end of the high vulnerability category, was found in the highest percentage (15.2) of anuran species. For salamanders, the respective values are 25.9% for an EVS of both 17 and 18, near the upper end of the range for the high vulnerability category, and for caecilians 50.0% for an EVS of both 11 and 12.

The total EVS scores generally increased from the low end of the scale (3) through most of the high end (14–18), with a single exception (a decrease from 53 to 21 species at scores 15 and 16). An EVS of 15 was found in the peak number of taxa (53), a score that falls within the high range of vulnerability.

Of the 378 total taxa, 50 (13.2%) fall into the low vulnerability category, 106 (28.0%) into the medium category, and 222 (58.7%) into the high category. Thus, six of every 10 Mexican amphibian species were judged as having the highest degree of vulnerability to environmental degradation, and slightly more than one-seventh the lowest degree.

This considerable increase in the absolute and relative numbers from the low portion, through the medium portion, to the high portion differs somewhat from the results published for amphibians and reptiles for several Central American countries in Wilson et al. (2010). Acevedo et al. (2010) reported 89 species (23.2%) with low scores, 179 (46.7%) with medium scores, and 115 (30.0%) with high scores for Guatemala. The same trend was reported for Honduras, where Townsend and Wilson (2010) indicated the corresponding values for amphib-

ians and reptiles as 71 (19.7%), 169 (46.8%), and 121 (33.5%). The comparable data for the Panamanian herpetofauna in Jaramillo et al. (2010) are 143 (33.3%), 165 (38.4%), and 122 (28.4%).

The principal reason that EVS scores are relatively high in Mexico is because of the high level of endemism and the concomitantly narrow range of geographical and ecological occurrence (Appendix 1). Of the 253 endemic amphibian species (139 anurans, 113 salamanders, and one caecilian), 125 (49.4%) were allocated a geographic distribution score of 6, signifying that these creatures are known only from the vicinity of their respective type localities; the remainder of the endemic species (128 [50.6%]) are more broadly distributed within the country (Appendix 1).

Of the 378 Mexican amphibian species, 128 (33.9%) are limited in ecological distribution to one formation (Appendix 1). Therefore, we emphasize that close to one-half of the country’s endemic amphibian species are not known to occur outside of the vicinity of their type localities. In addition, essentially one-third are not known to occur outside of a single forest formation. This situation imposes serious challenges in our attempt to conserve the endemic component of the strikingly important Mexican amphibian fauna.

Comparison of IUCN Categorizations and EVS Values

Table 3. Comparison of Environmental Vulnerability Scores (EVS) and IUCN categorizations for Mexican amphibians. Shaded area at the top encompasses low vulnerability category scores, and that at the bottom high vulnerability category scores.

EVS	IUCN categories							Totals
	Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Data Deficient	Not Evaluated	
3	—	—	—	—	4	—	—	4
4	—	—	—	—	3	—	—	3
5	—	—	—	—	3	—	—	3
6	—	—	—	—	3	—	1	4
7	1	—	—	—	8	—	—	9
8	—	—	2	2	6	—	2	12
9	1	1	1	1	10	—	1	15
10	1	2	1	—	9	—	2	15
11	1	2	7	—	13	—	—	23
12	5	4	3	4	13	2	1	32
13	4	12	5	5	6	3	1	36
14	12	11	7	2	8	6	3	49
15	22	8	5	2	3	10	3	53
16	4	9	4	2	1	1	—	21
17	15	17	6	2	1	7	2	50
18	21	13	3	1	—	9	1	48
19	1	—	—	—	—	—	—	1
Totals	88	79	44	21	91	38	17	378



Ixalotriton niger. The black jumping salamander is known only from the immediate vicinity of the type locality in northwestern Chiapas. Its EVS has been calculated as 18, placing it in the upper portion of the high vulnerability category, and its IUCN status as Critically Endangered. This individual came from the type locality and was used as part of the type series in the description of the species by Wake and Johnson (1989). The genus *Ixalotriton* is endemic to Mexico, and contains one other species (*I. parvus*). Photo by David B. Wake.



Pseudoeurycea longicauda. The endemic long-tailed false brook salamander is distributed in the Transverse Volcanic Axis of eastern Michoacán and adjacent areas in the state of México. Its EVS has been determined as 17, placing it in the middle of the high vulnerability category, and its IUCN status as Endangered. This individual came from Zitácuaro, Michoacán, near the border with the state of México. Photo by Iván Trinidad Ahumada-Carrillo.

We noted in Wilson et al. (2013: 18) that, “Since the IUCN categorizations and EVS values both measure the degree of environmental threat impinging on a given species, a certain degree of correlation between the results, using the two measures, is expected.” They further indicated that Townsend and Wilson (2010) demonstrated this to be the case with the Honduran herpetofauna. Wilson et al. (2013: 22) concluded, however, that, “the results of the EVS analysis are nearly the reverse of those obtained from the IUCN categorizations.”

We compared the results of these two conservation measures in Table 3, expecting that our results for the Mexican amphibians would be more consistent with those obtained for the Honduran herpetofauna (Townsend and Wilson 2010) than those garnered for the Mexican reptiles (Wilson et al. 2013).

1. Nature of the IUCN categorizations in Table 3

Like Wilson et al. (2013), we used the “Not Evaluated” category (IUCN 2010), since 17 species (4.5%) have not been evaluated at the IUCN Red List website, and 38 (10.1%) were evaluated as “Data Deficient” (www.iucnredlist.org; accessed 08 May 2013). Thus, the IUCN conservation status of 55 (14.6%) of the total amphibian species remained undetermined. A greater proportion of the Mexican amphibians, however, were assessed based on the IUCN categorizations (323 species [85.4%]) than the Mexican reptiles (Wilson et al. 2013).

2. Pattern of mean EVS vs. IUCN categorizations

In order to more precisely determine the relationship between the IUCN categorizations and the EVS, we calculated the mean EVS for each of the IUCN columns in Table 3, including for the NE species and the total species. The results are as follows: CR (88 spp.) = 15.5 (range 7–19); EN (79 spp.) = 15.1 (9–18); VU (44 spp.) = 13.8 (8–18); NT (21 spp.) = 13.3 (8–18); LC (91 spp.) = 10.0 (3–17); DD (38 spp.) = 15.6 (12–18); NE (17 spp.) = 12.6 (6–18); and total (378 spp.) = 13.7 (3–19). The results of these data show that the mean EVS decreases steadily from the CR category (15.5) through the EN (15.1), VU (13.8), and NT (13.3) categories to the LC category (10.0). This pattern of decreasing values was expected. In addition, the mean value for the DD species (15.6) is closest to that for the CR species. As we stated with regard to Mexican reptiles (Wilson et al. 2013: 22), “this indicates what we generally have suspected about the DD category, i.e., that the species placed in this category likely will fall into the EN or CR categories when (and if) their conservation status is better understood. Placing species in this category is of little benefit to determining their conservation status, however, since once sequestered with this designation their significance tends to be downplayed.” Wilson et al. (2013) demonstrated that this problem was more significant with Mexican reptiles, given that 118 species were evaluated as DD, which provided the impetus to work on the 38 amphibian

Table 4. Comparison of Environmental Vulnerability Scores for Mexican amphibian and reptile species, arranged by major groups. Shaded area to the left encompasses low vulnerability scores, and to the right high vulnerability scores.

Major groups	Number of species	Environmental Vulnerability Scores																	
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Anurans	237	4	3	3	4	9	12	14	13	20	25	29	36	30	8	14	12	1	—
Percentages	—	1.7	1.3	1.3	1.7	3.8	5.1	5.9	5.4	8.4	10.5	12.2	15.2	12.7	3.4	5.9	5.1	0.4	—
Salamanders	139	—	—	—	—	—	—	1	2	2	6	7	13	23	13	36	36	—	—
Percentages	—	—	—	—	—	—	—	0.7	1.4	1.4	4.3	5.0	9.4	16.6	9.4	25.9	25.9	—	—
Caecilians	2	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—
Percentages	—	—	—	—	—	—	—	—	—	50.0	50.0	—	—	—	—	—	—	—	—
Amphibian Totals	378	4	3	3	4	9	12	15	15	23	32	36	49	53	21	50	48	1	—
Percentages	—	1.0	0.8	0.8	1.0	2.4	3.2	4.0	4.0	6.1	8.5	9.5	13.0	14.0	5.5	13.2	12.7	0.3	—
Crocodylians	3	—	—	—	—	—	—	—	—	—	—	1	1	—	1	—	—	—	—
Percentages	—	—	—	—	—	—	—	—	—	—	—	33.3	33.3	—	33.3	—	—	—	—
Turtles	42	—	—	—	—	—	1	—	3	1	1	3	8	6	4	3	5	6	1
Percentages	—	—	—	—	—	—	2.4	—	7.1	2.4	2.4	7.1	19.0	14.3	9.5	7.1	11.9	14.3	2.4
Lizards	409	—	—	1	3	6	11	12	15	26	39	49	54	67	77	37	10	2	—
Percentages	—	—	—	0.2	0.7	1.5	2.7	2.9	3.7	7.1	9.5	12.0	13.2	16.4	18.8	9.0	2.4	0.5	—
Snakes	382	1	1	7	10	9	19	17	30	25	31	46	52	50	44	24	9	7	—
Percentages	—	0.3	0.3	1.8	2.6	2.4	5.0	4.5	7.9	6.5	8.1	12.0	13.6	13.1	11.5	6.3	2.4	1.8	—
Reptile Totals	836	1	1	8	13	15	31	30	46	53	71	99	115	123	126	64	24	15	1
Percentages	—	0.1	0.1	1.0	1.6	1.8	3.7	3.6	5.5	6.3	8.5	11.8	13.8	14.7	15.1	7.8	2.9	1.8	0.1



Dermophis oaxacae. The endemic Oaxacan caecilian is distributed in Colima, Jalisco, Michoacán, Guerrero, Oaxaca, and Chiapas. Its EVS has been calculated as 12, placing it in the middle portion of the medium vulnerability category, and its IUCN status as Data Deficient. This individual was found on the road at Ixtlahuacán, Colima. Photo by Jacobo Reyes-Velasco.

species assessed as DD with those occupying the threat categories (CR, EN, and VU) to arrive at a total of 249 species (65.9% of the total amphibian fauna). The EVS range for these DD species (12–18) falls within that for the threat species as a whole (7–19) and the mean for all the four categories becomes 15.1, the same as that for the EN species alone. So, if the DD species can be considered “threat species in disguise,” then close to two-thirds of the Mexican amphibian species would be considered under the threat of extinction.

The EVS for the 17 Mexican amphibian species that have not been evaluated by the IUCN range from 6 to 18 (mean = 12.6). These species are of significant conservation interest, inasmuch as the EVS of nine of them falls into the range of high vulnerability.

Based on the pattern of relationships between the LC species and their corresponding EVS, this IUCN category apparently has become a “dumping ground” for a sizable number of Mexican amphibians (91; 24.1% of the amphibian fauna) and like Wilson et al. (2013: 22) concluded for Mexican reptiles, we concur that “A more discerning look at both the LC and NE species might demonstrate that many should be partitioned into other IUCN categories, rather than the LC.” The range of EVS values for this category (3–17) is almost as broad as the range of EVS (3–19) for amphibians as a whole; 37 (40.7%) of these 91 species are relegated to the low vulnerabil-

ity range (3–9), 41 (45.0%) to the medium vulnerability range, and 13 (14.3%) to the high vulnerability range. Again, these results indicate that the LC category likely has been used rather indiscriminately and that the EVS algorithm provides a more useful conservation measure than the IUCN system of categories.

Comparison of EVS Values for Mexican Amphibians and Reptiles

One of our major reasons for writing this paper was to determine the EVS values for Mexican amphibians, so they could be compared to those calculated for Mexican reptiles in Wilson et al. (2013). Thus, we summarized the data in Table 2, and reduced them to the major group level in Table 4. We also reduced the data in Wilson et al. (2013: table 2) and placed them in our Table 4.

The data in this table indicate that the range of EVS values are comparable for amphibians (3–19) and reptiles (3–20). The EVS for the number of amphibian species essentially increases until a score of 15 is reached (53 species), and at 16 drops considerably (21 species) only to spike back up at 17 and 18 (50 and 48 species, respectively). The highest EVS value (19) was assigned to a single species (the fringe-limbed hyliid *Ecnomihyla echinata*). For the reptiles, the numbers and percentages also increase, with the peak (126 [15.1%]) reached at an

EVS of 16, and decreasing rapidly thereafter. As with amphibians, only a single species (the soft-shelled turtle *Apalone atra*) was assigned the highest EVS (20).

When the EVS values are arranged into low, medium, and high categories, the numbers and percentages of species are as follows (amphibians, followed by reptiles): low = 50 (13.2%), 99 (11.8%); medium = 106 (28.0%), 269, (32.2%); and high = 222 (58.8%), 468, (56.0%). The percentages for these two groups are comparable and arranged in the same order. The greatest concern is that in both amphibians and reptiles more than one-half of the species fall into the upper portion of the high vulnerability category, indicating that the Mexican herpetofauna is seriously imperiled.

Of the major groups of amphibians and reptiles, Mexican salamanders were judged the most imperiled. Of the 139 species known from the country, 121 (87.1%) were assessed in the high vulnerability category. The comparable figure for anurans is 101 (42.6%), less than one-half of that for salamanders. Among the reptiles, lizards were judged more threatened than snakes. Of the lizards, 247 (60.4%) fall within the high vulnerability category; the comparable figures for snakes are 186 and 48.7%. Turtles, although fewer in numbers, are more threatened than other reptiles, with 33 species (78.6%) in the high vulnerability category.

In the final analysis, although amphibians are acknowledged widely as threatened on a global basis, a fair accounting of the worldwide conservation status of most reptiles remains unavailable. Our use of the EVS measure for Mexican amphibians and reptiles demonstrates that both groups are in grave peril, and we expect that this situation will worsen exponentially in the coming decades.

Discussion

Global amphibian population decline has occupied the attention of herpetologists since the late 1980s (Gascon et al. 2007). In the years that followed, the Global Amphibian Assessment (GAA) was undertaken (Stuart et al. 2004), which uncovered the startling conclusions discussed in the Introduction. As noted in the foreword to Gascon et al. (2007: 2), “the first GAA documented the breadth of amphibian losses worldwide and made it clear that business as usual—the customary conservation approaches and practices—were not working.” As a result, an Amphibian Conservation Summit was convened in September 2005, which resulted in a putatively comprehensive Amphibian Conservation Action Plan (ACAP; Gascon et al. 2007). The ACAP declaration proposed (p. 59) that, “Four kinds of intervention are needed to conserve amphibians, all of which need to be started immediately:

1. Expanded understanding of the causes of declines and extinctions

2. Ongoing documentation of amphibian diversity, and how it is changing
3. Development and implementation of long-term conservation programmes
4. Emergency responses to immediate crises.”

We maintain that the ACAP does an admirable job of examining many of the issues directly related to amphibian decline, but this examination essentially stops after considering the proximate symptoms of the problem. Nonetheless, as noted by Wilson and Townsend (2010: 774), “problems created by humans, i.e., overpopulation and its sequelae, are not solved by treating only their symptoms, e.g., organismic endangerment.” Consequently, trying to deal with a symptom of overpopulation and resource overuse and abuse, such as amphibian decline, will create only limited short-term responses, instead of lasting solutions to the fundamental problems tied to the impact of humans. Thus, ultimately, amphibian decline will not be successfully addressed.

The fundamental problem is that humans have not created a sustainable existence for themselves. Understanding why not is simple through examination of the principles of sustainability elaborated by Miller and Spoolman (2012: 6), as follows:

- “Nature has sustained itself for billions of years by relying on solar energy, biodiversity, and nutrient cycling.
- Our lives and economies depend on energy from the sun and on natural resources and natural services (*natural capital*) provided by the earth.
- As our ecological footprints grow, we are depleting and degrading more of the earth’s natural capital.
- Major causes of environmental problems are population growth, wasteful and unsustainable resource use, poverty, and not including the harmful environmental costs of resource use in the market prices of goods and services.
- Our environmental worldview plays a key role in determining whether we live unsustainably or more sustainably.
- Living sustainably means living off the earth’s natural income without depleting or degrading the natural capital that supplies it.”

Living unsustainably is a consequence of unregulated human population growth that generates the overuse and abuse of renewable and non-renewable resources, and dependence on a cost-accounting system that ignores factoring in clean up expenses in determining how goods and services are priced. Life-sustaining resources are not distributed equitably among people, but along a scale ranging from very high to very low. Poverty is the consequence of existing at the low end of the scale, where people are unable to meet their basic needs for adequate food and water, clothing, or shelter (Raven and Berg 2004).

Environmental scientists use the concept of *ecological footprint* to express “the average amount of land and ocean needed to supply an individual with food, energy, water, housing, transportation, and waste disposal” (Raven and Berg 2004: G-5). The global ecological footprint has increased over the years to the point that the Global Footprint Network calculated it would take “1.5 years to generate the renewable resources used in 2008” (WWF Living Planet Report 2012: 40). “Humanity’s annual demand on the natural world has exceeded what the Earth can renew in a year since the 1970s,” which has created a so-called “ecological overshoot” (WWF Living Planet Report 2012: 40). Thus, Earth’s capital (its biocapacity) is being depleted on a continually growing basis, and the planet is becoming less capable of supporting life in general, and human life in particular. Estimates indicate that by the year 2050, under a “business as usual” scenario, it would require an equivalent of 2.9 planets to support the amount of humanity expected to exist at that time (WWF Living Planet Report 2012: 101).

The World Wildlife Fund promulgated its “One Planet perspective,” which “explicitly proposes to manage, govern and share natural capital within the Earth’s ecological boundaries. In addition to safeguarding and restoring this natural capital, WWF seeks better choices along the entire system of production and consumption, supported by redirected financial flows and more equitable resource governance. All of this, and more, is required to decouple human development from unsustainable consumption (moving away from material and energy-intensive commodities), to avoid greenhouse gas emissions, to maintain ecosystem integrity, and to promote pro-poor growth and development” (WWF Living Planet Report 2012: 106).

Only within this context will the provisions of ACAP have the desired effects, i.e., to preserve the portion of natural capital represented by amphibians. Thus, in writing about the conservation status of the amphibians of Mexico, we are constructing our conclusions and recommendations in light of these global imperatives.

Conclusions and Recommendations

We structured our conclusions and recommendations after those of Wilson and Townsend (2010) for the entire Mesoamerican herpetofauna, refining them specifically for the Mexican amphibian fauna, as follows:

1. Given that Mexico contains the highest level of amphibian diversity and endemism in the Mesoamerican biodiversity hotspot, our most fundamental recommendation is that protection of this aspect of the Mexican patrimony should be made a major component of the management strategy of the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). In turn, that strategy needs to be incorporated into an overall plan for a sus-

tainable future for Mexico, of which the most critical component is to “explicitly integrate population dynamics (size, growth rate, composition, location and migration) and per capita consumption trends into national planning policies to support a better balance between population and available resources” (WWF Living Planet Report 2012: 121).

2. All organisms have intrinsic and extrinsic value, especially as components of healthily functioning ecosystems, but we believe that although conservation efforts should extend to all species in a given area, most interest should be focused on species with a limited distribution (i.e., endemic species). The rationale for this position is that funds to support conservation initiatives have remained scarce, although this situation will have to change in the near future. The principal regions of Mexican amphibian endemism are the Sierra Madre Oriental, the Sierra Madre del Sur, and the Mesa Central, in the order listed. Unfortunately, about 39% of Mexico’s population occupies the Mesa Central (Flores-Villela et al. 2010). Inasmuch as this concentrated population will continue to grow into the foreseeable future, not only as a consequence of the rate of natural increase (1.4% in Mexico), but also because of the increase in the percentage of the population attracted to the large cities of the Mesa Central (Guadalajara, León, México, Morelia, Salamanca, and others; Flores-Villela et al. 2010), it is critically important to make the amphibian fauna of the Mesa Central a fundamental component of the national plan for biodiversity protection by SEMARNAT.
3. Oscar Flores-Villela and his colleagues produced highly significant conservation analyses (Flores-Villela 1993; Flores-Villela and Gerez 1994; Ochoa-Ochoa and Flores-Villela 2006; Flores-Villela et al. 2010) that have documented the centers of diversity and endemism of the Mexican herpetofauna. Given the large disparity between these centers and the placement of protected areas in the country, we can only echo the conclusions of Flores-Villela et al. (2010: 313) that, “Given the great importance of the herpetofauna of the Central Highlands of Mexico, both in terms of its diversity and endemism, appropriate steps need to be taken quickly to establish protected areas around the center of herpetofaunal endemism in the Sierra Madre del Sur, and to reassess the ability of the protected areas already established in the Mesa Central to encompass their centers of endemism.” A similar recommendation can be made with respect to the other centers, e.g., the Sierra Madre Oriental, which has been even more ignored than areas in the Central Highlands (Lavín et al. 2010).

4. Finding ways to use biodiversity sustainably must become a fundamental goal for all humanity. The steps necessary to achieve this end are not difficult to envision; the problem lies in marshaling the paradigm shift necessary to make the transition. The major steps involve: (a) creating a reality-based educational system that will prepare people for the world as it is and will come to be, instead of the way people wish it were; (b) integrating educational reform into a broad-based plan for governmental and economic reform founded on principles of equality, shared responsibility, and commitment to a sustainable future for humanity and the natural world; (c) using governmental and economic reform to design a global society structured to exist within the limits of nature; and (d) basing a society on the notion that everyone must work toward this end. Within such overarching goals, the task of learning the best way to catalogue, protect, and make sustainable use of the world's organisms is a huge undertaking. New molecular-based technology, however, is allowing for a better understanding of biological diversity, which is much greater than we previously envisioned. Because of the accelerating rate at which we are losing biological diversity, biologists are faced with helping humanity adopt a worldview in which all species matter, and that the sustainability of humans will depend on reforming our society based on the framework for survival tested by the process of natural selection over the last 3.5 billion years life has occupied our planet (Beattie and Ehrlich 2004).
5. In 2012, the United Nations Secretary-General's High-level Panel on Global Sustainability produced a seminal report entitled "Resilient People, Resilient Planet: A Future Worth Choosing." In a vision statement (p. 13), the panel introduced the concept of "tipping points," as follows: "The current global development model is unsustainable. We can no longer assume that our collective actions will not trigger tipping points as environmental thresholds are breached, risking irreversible damage to both ecosystems and human communities. At the same time, such thresholds should not be used to impose arbitrary growth ceilings on developing countries seeking to lift their people out of poverty. Indeed, if we fail to resolve the sustainable development dilemma, we run the risk of condemning up to 3 billion members of our human family to a life of endemic poverty. Neither of these outcomes is acceptable, and we must find a new way forward." The panel also pointed out (p. 14) that "it is time for bold global efforts, including launching a major global scientific initiative, to strengthen the interface between science and policy. We must define, through science, what sci-

entists refer to as 'planetary boundaries,' 'environmental thresholds,' and 'tipping points.' On p. 23, they emphasize that, "awareness is growing of the potential for passing 'tipping points' beyond which environmental change accelerates, has the potential to become self-perpetuating, and may be difficult or even impossible to reverse." Environmental scientists have warned of this eventuality for decades; most of the world's people just have not listened. The Stockholm Resilience Centre (www.stockholmresilience.org), however, has exposed a number of "planetary boundaries," defined as certain thresholds or tipping points beyond which there is the "risk of irreversible and abrupt environmental change" (Box 2 on p. 24 of the UN panel report). The Stockholm Resilience Centre sponsored a group of scientists (Rockström et al. 2009) that identified nine planetary boundaries, including: "climate change, rate of biodiversity loss, biogeochemical flows (both nitrogen and phosphorus), stratospheric ozone depletion, ocean acidification, global freshwater use, change in land use, atmospheric aerosol loading and chemical pollution." The scientists estimated that "human activity appears to have already transgressed the [planetary] boundaries associated with climate change, rate of biodiversity loss and changes to the global nitrogen cycle." Furthermore, "humanity may soon be approaching the boundaries for interference with the global phosphorous cycle, global freshwater use, ocean acidification and global change in land use." Finally, they concluded that, "the boundaries are strongly interlinked, so that crossing one may shift others and even cause them to be overstepped." As a consequence of these realities, governments across the globe are faced with the choice of continuing to do "business as usual," ultimately spilling over all the planetary boundaries and ending up in a world in which all of our options have been exhausted except for the last one...the option to fail, or to pull together to develop a human existence lying within planetary boundaries in order to define a "safe operating space for humanity." Our chances to avoid the one and succeed with the other will depend on how well humanity is able to embrace new ways of thinking about our problems and enlist the help of groups of people who traditionally have been marginalized—especially women and the young. These words apply to Mexico, as they do to all other countries in the world.

The three authors of this work are herpetologists who specialize in research on amphibians and reptiles in Mesoamerica. This paper focuses on the conservation status of the amphibians of Mexico, and follows a similar effort on the reptiles (Wilson et al. 2013). We demonstrated by using both the IUCN categorizations and EVS measure

that the Mexican amphibian fauna is one of the most seriously threatened of any existing in the world. All indications suggest that humans have transgressed the planetary boundaries associated with biodiversity loss, and there is no time to lose to reverse this dismantling trend or our descendants will be left to conclude that our generation condemned them to an environmentally impoverished world by our inaction. In the final analysis, life on Earth has survived five prior mass extinction events; humanity's job now is to survive the one of its own making.

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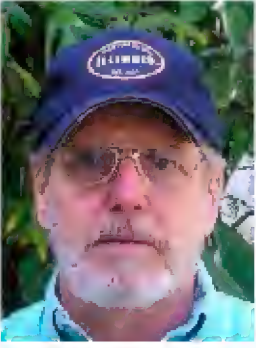
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Conservation reassessment of Mexican amphibians



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Vicente Mata-Silva is a herpetologist interested in ecology, conservation, and the monitoring of amphibians and reptiles in Mexico and the southwestern United States. His bachelor’s thesis compared herpetofaunal richness in Puebla, México, in habitats with different degrees of human related disturbance. Vicente’s master’s thesis focused primarily on the diet of two syntopic whiptail species of lizards, one unisexual and the other bisexual, in the Trans-Pecos region of the Chihuahuan Desert. Currently, he is a postdoctoral research fellow at the University of Texas at El Paso, where his work focuses on rattlesnake populations in their natural habitat. His dissertation was on the ecology of the rock rattlesnake, *Crotalus lepidus*, in the northern Chihuahuan Desert. To date, Vicente has authored or co-authored 34 peer-reviewed scientific publications.

Appendix 1. Comparison of the IUCN Ratings from the Red List Website (updated to 08 May 2013) and Environmental Vulnerability Scores for 378 Mexican Amphibians. See text for explanations of the IUCN and EVS rating systems. * = species endemic to Mexico.

Species	IUCN rating	Environmental Vulnerability Score			
		Geographic Distribution	Ecological Distribution	Reproductive Mode	Total Score
Order Anura (237 species)					
Family Bufonidae (35 species)					
<i>Anaxyrus boreus</i>	NT	3	4	1	8
<i>Anaxyrus californicus</i>	EN	4	7	1	12
<i>Anaxyrus cognatus</i>	LC	3	5	1	9
<i>Anaxyrus compactilis</i> *	LC	5	8	1	14
<i>Anaxyrus debilis</i>	LC	1	5	1	7
<i>Anaxyrus kelloggi</i> *	LC	5	8	1	14
<i>Anaxyrus mexicanus</i> *	NT	5	7	1	13
<i>Anaxyrus punctatus</i>	LC	1	3	1	5
<i>Anaxyrus retiformis</i>	LC	4	7	1	12
<i>Anaxyrus speciosus</i>	LC	4	7	1	12
<i>Anaxyrus woodhousii</i>	LC	3	6	1	10
<i>Incilius alvarius</i>	LC	4	6	1	11
<i>Incilius aurarius</i>	NE	4	8	1	13
<i>Incilius bocourti</i>	LC	4	6	1	11
<i>Incilius campbelli</i>	NT	4	8	1	13
<i>Incilius canaliferus</i>	LC	4	3	1	8
<i>Incilius cavifrons</i> *	EN	5	7	1	13
<i>Incilius coocifer</i>	LC	3	5	1	9
<i>Incilius cristatus</i> *	CR	5	8	1	14
<i>Incilius cycladen</i> *	VU	5	8	1	14
<i>Incilius gemmifer</i> *	EN	6	8	1	15
<i>Incilius luetkenii</i>	LC	3	3	1	7
<i>Incilius macrocristatus</i>	VU	4	6	1	11
<i>Incilius marmoreus</i> *	LC	5	5	1	11
<i>Incilius mazatlanensis</i> *	LC	5	6	1	12
<i>Incilius mccoysi</i> *	NE	5	8	1	14
<i>Incilius nebulifer</i>	LC	1	4	1	6
<i>Incilius occidentalis</i> *	LC	5	5	1	11
<i>Incilius perplexus</i> *	EN	5	5	1	11
<i>Incilius pisinnus</i> *	DD	6	8	1	15
<i>Incilius spiculatus</i> *	EN	5	7	1	13
<i>Incilius tacanensis</i>	EN	4	4	1	9
<i>Incilius tutelarius</i>	EN	4	5	1	10
<i>Incilius valliceps</i>	LC	3	2	1	6
<i>Rhinella marina</i>	LC	1	1	1	3
Family Centrolenidae (1 species)					
<i>Hyalinobatrachium fleischmanni</i>	LC	3	4	3	10
Family Craugastoridae (39 species)					
<i>Craugastor alfredi</i>	VU	2	5	4	11
<i>Craugastor amniscola</i>	DD	4	6	4	14
<i>Craugastor augusti</i>	LC	2	2	4	8
<i>Craugastor batrachylus</i> *	DD	6	8	4	18

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<i>Craugastor berkenbuschii</i> *	NT	5	5	4	14
<i>Craugastor brocchi</i>	VU	4	6	4	14
<i>Craugastor decoratus</i> *	VU	5	6	4	15
<i>Craugastor galacticorhinis</i> *	NE	6	8	4	15
<i>Craugastor glaucus</i> *	CR	6	8	4	18
<i>Craugastor greggi</i>	CR	4	7	4	15
<i>Craugastor guerreroensis</i> *	CR	6	8	4	18
<i>Craugastor hobartsmithi</i> *	EN	5	6	4	15
<i>Craugastor laticeps</i>	NT	4	4	4	12
<i>Craugastor lineatus</i>	CR	4	7	4	15
<i>Craugastor loki</i>	LC	2	4	4	10
<i>Craugastor matudai</i>	VU	4	7	4	15
<i>Craugastor megalotympanum</i> *	CR	6	8	4	18
<i>Craugastor mexicanus</i> *	LC	5	7	4	16
<i>Craugastor montanus</i> *	EN	6	8	4	18
<i>Craugastor occidentalis</i> *	DD	5	4	4	13
<i>Craugastor omiltemanus</i> *	EN	5	7	4	16
<i>Craugastor palenque</i>	DD	4	7	4	15
<i>Craugastor pelorus</i> *	DD	5	6	4	15
<i>Craugastor polymniae</i> *	CR	6	8	4	18
<i>Craugastor pozo</i> *	CR	6	7	4	17
<i>Craugastor pygmaeus</i>	VU	2	3	4	9
<i>Craugastor rhodopsis</i> *	VU	5	5	4	14
<i>Craugastor rugulosus</i> *	LC	5	4	4	13
<i>Craugastor rupinius</i>	LC	4	5	4	13
<i>Craugastor saltator</i> *	NE	5	6	4	15
<i>Craugastor silvicola</i> *	EN	6	8	4	18
<i>Craugastor spatulatus</i> *	EN	5	7	4	16
<i>Craugastor stuarti</i>	EN	4	7	4	15
<i>Craugastor tarahumaraensis</i> *	VU	5	8	4	17
<i>Craugastor taylori</i> *	DD	6	8	4	18
<i>Craugastor uno</i> *	EN	5	8	4	17
<i>Craugastor vocalis</i> *	LC	5	4	4	13
<i>Craugastor vulcani</i> *	EN	6	7	4	17
<i>Craugastor yucatanensis</i> *	NT	5	8	4	17
Family Eleutherodactylidae (23 species)					
<i>Eleutherodactylus albolabris</i> *	NE	6	7	4	17
<i>Eleutherodactylus angustidigitorum</i> *	VU	5	8	4	17
<i>Eleutherodactylus cystignathoides</i>	LC	2	6	4	12
<i>Eleutherodactylus dennisi</i> *	EN	6	8	4	18
<i>Eleutherodactylus dilatus</i> *	EN	5	8	4	17
<i>Eleutherodactylus grandis</i> *	CR	6	8	4	18
<i>Eleutherodactylus guttilatus</i>	LC	2	5	4	11
<i>Eleutherodactylus interorbitalis</i> *	DD	5	6	4	15
<i>Eleutherodactylus leprus</i>	VU	2	6	4	12
<i>Eleutherodactylus longipes</i> *	VU	5	6	4	15
<i>Eleutherodactylus maurus</i> *	DD	5	8	4	17
<i>Eleutherodactylus modestus</i> *	VU	5	7	4	16
<i>Eleutherodactylus nitidus</i> *	LC	5	3	4	12

<i>Eleutherodactylus nivicolimae</i> *	VU	6	7	4	17
<i>Eleutherodactylus pallidus</i> *	DD	5	8	4	17
<i>Eleutherodactylus pipilans</i>	LC	2	5	4	11
<i>Eleutherodactylus rubrimaculatus</i>	VU	4	7	4	15
<i>Eleutherodactylus rufescens</i> *	CR	6	7	4	17
<i>Eleutherodactylus saxatilis</i> *	EN	5	8	4	17
<i>Eleutherodactylus syristes</i> *	EN	5	7	4	16
<i>Eleutherodactylus teretistes</i> *	DD	5	7	4	16
<i>Eleutherodactylus verrucipes</i> *	VU	5	7	4	16
<i>Eleutherodactylus verruculatus</i> *	DD	6	8	4	18
Family Hylidae (97 species)					
<i>Acris blanchardi</i>	NE	3	8	1	12
<i>Agalychnis callidryas</i>	LC	3	5	3	11
<i>Agalychnis dacnicolor</i> *	LC	5	5	3	13
<i>Agalychnis moreletii</i>	CR	1	3	3	7
<i>Anotheca spinosa</i>	LC	3	6	5	14
<i>Bromeliohyla bromeliacia</i>	EN	4	7	5	16
<i>Bromeliohyla dendroscarta</i> *	CR	5	7	5	17
<i>Charadrahyla altipotens</i> *	CR	5	6	1	12
<i>Charadrahyla chaneque</i> *	EN	5	7	1	13
<i>Charadrahyla nephila</i> *	VU	5	7	1	13
<i>Charadrahyla taeniopus</i> *	VU	5	7	1	13
<i>Charadrahyla tecuani</i> *	NE	6	8	1	15
<i>Charadrahyla trux</i> *	CR	6	7	1	14
<i>Dendropsophus ebraccatus</i>	LC	3	6	3	10
<i>Dendropsophus microcephalus</i>	LC	3	3	1	7
<i>Dendropsophus robertmertensi</i>	LC	4	4	1	9
<i>Dendropsophus sartori</i> *	LC	5	8	1	14
<i>Diaglena spatulata</i> *	LC	5	7	1	13
<i>Duellmanohyla chamulae</i> *	EN	6	7	1	13
<i>Duellmanohyla ignicolor</i> *	EN	6	7	1	14
<i>Duellmanohyla schmidtorum</i>	VU	4	3	1	8
<i>Ecnomiohyla echinata</i> *	CR	6	8	5	19
<i>Ecnomiohyla miotympanum</i> *	NT	5	3	1	9
<i>Ecnomiohyla valancifer</i> *	CR	6	7	5	18
<i>Exerodonta abdivita</i> *	DD	6	8	1	15
<i>Exerodonta bivocata</i> *	DD	6	8	1	15
<i>Exerodonta chimalapa</i> *	EN	6	5	1	12
<i>Exerodonta juanitae</i> *	VU	5	8	1	14
<i>Exerodonta melanomma</i> *	VU	5	5	1	11
<i>Exerodonta pinorum</i> *	VU	5	7	1	13
<i>Exerodonta smaragdina</i> *	LC	5	6	1	12
<i>Exerodonta sumichrasti</i> *	LC	5	3	1	9
<i>Exerodonta xera</i> *	VU	5	8	1	14
<i>Hyla arboricola</i> *	DD	5	6	1	12
<i>Hyla arenicolor</i>	LC	2	4	1	7
<i>Hyla euphorbiacea</i> *	NT	5	7	1	13
<i>Hyla eximia</i> *	LC	5	4	1	10
<i>Hyla plicata</i> *	LC	5	5	1	11

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<i>Hyla walkeri</i>	VU	4	6	1	11
<i>Hyla wrightorum</i>	LC	2	6	1	9
<i>Megastomatohyla mixe*</i>	CR	6	8	1	15
<i>Megastomatohyla mixomaculata*</i>	EN	5	8	1	14
<i>Megastomatohyla nubicola*</i>	EN	5	8	1	14
<i>Megastomatohyla pellita*</i>	CR	6	7	1	14
<i>Plectrohyla acanthodes</i>	CR	4	7	1	12
<i>Plectrohyla ameibothalame*</i>	DD	6	8	1	15
<i>Plectrohyla arborescandens*</i>	EN	5	5	1	11
<i>Plectrohyla avia</i>	CR	4	8	1	13
<i>Plectrohyla bistincta*</i>	LC	5	3	1	9
<i>Plectrohyla calthula*</i>	CR	5	8	1	14
<i>Plectrohyla calvicollina*</i>	CR	6	7	1	14
<i>Plectrohyla celata*</i>	CR	6	7	1	14
<i>Plectrohyla cembra*</i>	CR	5	8	1	14
<i>Plectrohyla charadricola*</i>	EN	5	8	1	14
<i>Plectrohyla chryses*</i>	CR	6	7	1	14
<i>Plectrohyla crassa*</i>	CR	5	8	1	14
<i>Plectrohyla cyanomma*</i>	CR	5	8	1	14
<i>Plectrohyla cyclada*</i>	EN	5	8	1	14
<i>Plectrohyla ephemera*</i>	CR	6	8	1	15
<i>Plectrohyla guatemalensis</i>	CR	4	4	1	9
<i>Plectrohyla hartwegi</i>	CR	4	5	1	10
<i>Plectrohyla hazelae*</i>	CR	5	6	1	12
<i>Plectrohyla ixil</i>	CR	4	7	1	12
<i>Plectrohyla labedactyla*</i>	DD	6	8	1	15
<i>Plectrohyla lacertosa*</i>	EN	5	8	1	14
<i>Plectrohyla matudai</i>	VU	4	6	1	11
<i>Plectrohyla miahuatlanensis*</i>	DD	6	8	1	15
<i>Plectrohyla mykter*</i>	EN	5	7	1	13
<i>Plectrohyla pachyderma*</i>	CR	6	8	1	15
<i>Plectrohyla pentheter*</i>	EN	5	7	1	13
<i>Plectrohyla psarosema*</i>	CR	6	8	1	15
<i>Plectrohyla pychnochila*</i>	CR	6	8	1	15
<i>Plectrohyla robertsorum*</i>	EN	5	7	1	13
<i>Plectrohyla sabrina*</i>	CR	5	8	1	14
<i>Plectrohyla sagorum</i>	EN	4	5	1	10
<i>Plectrohyla siopela*</i>	CR	6	8	1	15
<i>Plectrohyla thorectes*</i>	CR	5	7	1	13
<i>Pseudacris cadaverina</i>	LC	4	6	1	11
<i>Pseudacris clarki</i>	LC	3	8	1	12
<i>Pseudacris hypochondriaca</i>	NE	4	4	1	9
<i>Ptychohyla acrochorda*</i>	DD	6	7	1	14
<i>Ptychohyla erythromma*</i>	EN	5	7	1	13
<i>Ptychohyla euthysanota</i>	NT	4	3	1	8
<i>Ptychohyla leonhardschultzei*</i>	EN	5	6	1	12
<i>Ptychohyla macrotympanum</i>	CR	4	6	1	11
<i>Ptychohyla zophodes*</i>	DD	5	7	1	13
<i>Scinax staufferi</i>	LC	2	1	1	4

<i>Smilisca baudinii</i>	LC	1	1	1	3
<i>Smilisca cyanosticta</i>	NT	4	7	1	12
<i>Smilisca dentata</i> *	EN	5	8	1	14
<i>Smilisca fodiens</i>	LC	2	5	1	8
<i>Tlalocohyla godmani</i> *	VU	5	7	1	13
<i>Tlalocohyla loquax</i>	LC	3	3	1	7
<i>Tlalocohyla picta</i>	LC	2	5	1	8
<i>Tlalocohyla smithii</i> *	LC	5	5	1	11
<i>Trachycephalus typhonius</i>	LC	1	2	1	4
<i>Tripurion petasatus</i>	LC	4	5	1	10
Family Leiuperidae (1 species)					
<i>Engystomops pustulosus</i>	LC	3	2	2	7
Family Leptodactylidae (2 species)					
<i>Leptodactylus fragilis</i>	LC	1	2	2	5
<i>Leptodactylus melanonotus</i>	LC	1	3	2	6
Family Microhylidae (6 species)					
<i>Gastrophryne elegans</i>	LC	2	5	1	8
<i>Gastrophryne mazatlanensis</i>	NE	2	5	1	8
<i>Gastrophryne olivacea</i>	LC	3	5	1	9
<i>Hypopachus barberi</i>	VU	4	5	1	10
<i>Hypopachus ustus</i>	LC	2	4	1	7
<i>Hypopachus variolosus</i>	LC	2	1	1	4
Family Ranidae (28 species)					
<i>Lithobates berlandieri</i>	LC	4	2	1	7
<i>Lithobates brownorum</i>	NE	4	3	1	8
<i>Lithobates catesbeianus</i>	LC	3	6	1	10
<i>Lithobates chichicuahutla</i> *	CR	6	8	1	15
<i>Lithobates chiricahuensis</i>	VU	4	6	1	11
<i>Lithobates dunni</i> *	EN	5	8	1	14
<i>Lithobates forreri</i>	LC	1	1	1	3
<i>Lithobates johnei</i> *	EN	5	8	1	14
<i>Lithobates lemosespinali</i> *	DD	5	8	1	14
<i>Lithobates macroglossa</i>	VU	4	7	1	12
<i>Lithobates maculatus</i>	LC	3	1	1	5
<i>Lithobates magnaocularis</i> *	LC	5	6	1	12
<i>Lithobates megapoda</i> *	VU	5	8	1	14
<i>Lithobates montezumae</i> *	LC	5	7	1	13
<i>Lithobates neovolcanicus</i> *	NT	5	7	1	13
<i>Lithobates omiltemanus</i> *	CR	5	7	1	13
<i>Lithobates psilonota</i> *	DD	5	8	1	14
<i>Lithobates pueblae</i> *	CR	6	8	1	15
<i>Lithobates pustulosus</i> *	LC	5	3	1	9
<i>Lithobates sierramadrensis</i> *	VU	5	7	1	13
<i>Lithobates spectabilis</i> *	LC	5	6	1	12
<i>Lithobates tarahumarae</i>	VU	2	5	1	8
<i>Lithobates tlaloci</i> *	CR	6	8	1	15
<i>Lithobates vaillanti</i>	LC	3	5	1	9
<i>Lithobates yavapaiensis</i>	LC	4	7	1	12
<i>Lithobates zweifeli</i> *	LC	5	5	1	11

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<i>Rana boylei</i>	NT	3	8	1	12
<i>Rana draytonii</i>	LC	3	6	1	10
Family Rhinophrynidae (1 species)					
<i>Rhinophrynus dorsalis</i>	LC	2	5	1	8
Family Scaphiopodidae (4 species)					
<i>Scaphiopus couchii</i>	LC	1	1	1	3
<i>Spea bombifrons</i>	NE	3	6	1	10
<i>Spea hammondi</i>	LC	3	8	1	12
<i>Spea multiplicata</i>	NE	1	4	1	6
Order Caudata (139 species)					
Family Ambystomatidae (18 species)					
<i>Ambystoma altamirani</i> *	EN	5	7	1	13
<i>Ambystoma amblycephalum</i> *	CR	6	6	1	13
<i>Ambystoma andersoni</i> *	CR	6	8	1	15
<i>Ambystoma bombypellum</i> *	CR	6	8	1	15
<i>Ambystoma dumerilii</i> *	CR	6	8	1	15
<i>Ambystoma flavipiperatum</i> *	DD	6	7	1	14
<i>Ambystoma granulatum</i> *	CR	6	7	1	14
<i>Ambystoma leorae</i> *	CR	6	8	1	15
<i>Ambystoma lermaense</i> *	CR	6	8	1	15
<i>Ambystoma mavortium</i>	NE	3	6	1	10
<i>Ambystoma mexicanum</i> *	CR	6	8	1	15
<i>Ambystoma ordinatum</i> *	EN	5	7	1	13
<i>Ambystoma rivulare</i> *	DD	5	7	1	13
<i>Ambystoma rosaceum</i> *	LC	5	8	1	14
<i>Ambystoma silvense</i> *	DD	5	8	1	14
<i>Ambystoma subsalsum</i> *	NE	5	8	1	14
<i>Ambystoma taylori</i> *	CR	6	8	1	15
<i>Ambystoma velasci</i> *	LC	5	4	1	10
Family Plethodontidae (118 species)					
<i>Aneides lugubris</i>	LC	3	7	4	14
<i>Batrachoseps major</i>	LC	4	6	4	14
<i>Bolitoglossa alberchi</i> *	LC	6	5	4	15
<i>Bolitoglossa chinanteca</i>	NE	6	8	4	18
<i>Bolitoglossa engelhardti</i>	EN	4	7	4	15
<i>Bolitoglossa flavimembris</i>	EN	4	7	4	15
<i>Bolitoglossa flaviventris</i>	EN	4	5	4	13
<i>Bolitoglossa franklini</i>	EN	4	6	4	14
<i>Bolitoglossa hartwegi</i>	NT	4	4	4	12
<i>Bolitoglossa hermosa</i> *	NT	5	7	4	16
<i>Bolitoglossa lincolni</i>	NT	4	5	4	13
<i>Bolitoglossa macrinii</i> *	NT	5	6	4	15
<i>Bolitoglossa mexicana</i>	LC	4	3	4	11
<i>Bolitoglossa mulleri</i>	VU	4	7	4	15
<i>Bolitoglossa oaxacensis</i> *	DD	5	8	4	17
<i>Bolitoglossa occidentalis</i>	LC	4	3	4	11
<i>Bolitoglossa platydactyla</i> *	NT	5	6	4	15
<i>Bolitoglossa rietzi</i> *	EN	6	6	4	16
<i>Bolitoglossa rostrata</i>	VU	4	6	4	14

<i>Bolitoglossa rufescens</i>	LC	1	4	4	9
<i>Bolitoglossa stuarti</i>	DD	4	7	4	15
<i>Bolitoglossa veracrucis</i> *	EN	6	7	4	17
<i>Bolitoglossa yucatana</i>	LC	4	7	4	15
<i>Bolitoglossa zapoteca</i> *	DD	6	8	4	18
<i>Chiropterotriton arboreus</i> *	CR	6	8	4	18
<i>Chiropterotriton chiropterus</i> *	CR	6	6	4	16
<i>Chiropterotriton chondrostega</i> *	EN	5	8	4	17
<i>Chiropterotriton cracens</i> *	EN	6	7	4	17
<i>Chiropterotriton dimidiatus</i> *	EN	6	7	4	17
<i>Chiropterotriton lavae</i> *	CR	6	8	4	18
<i>Chiropterotriton magnipes</i> *	CR	6	6	4	16
<i>Chiropterotriton mosaueri</i> *	DD	6	8	4	18
<i>Chiropterotriton multidentatus</i> *	EN	5	6	4	15
<i>Chiropterotriton orculus</i> *	VU	6	8	4	18
<i>Chiropterotriton priscus</i> *	NT	6	6	4	16
<i>Chiropterotriton terrestris</i> *	CR	6	8	4	18
<i>Cryptotriton alvarezdeltoroi</i> *	EN	6	8	4	18
<i>Dendrotriton megarhinus</i> *	VU	6	7	4	17
<i>Dendrotriton xoloccalcae</i> *	VU	6	8	4	18
<i>Ensatina eschscholtzii</i>	LC	3	7	4	14
<i>Ensatina klauberi</i>	NE	4	6	4	14
<i>Ixalotriton niger</i> *	CR	6	8	4	18
<i>Ixalotriton parvus</i> *	CR	6	8	4	18
<i>Nyctanolis pernix</i>	EN	4	7	4	15
<i>Oedipina elongata</i>	LC	4	7	4	15
<i>Parvimolge townsendi</i> *	CR	5	7	4	16
<i>Pseudoeurycea ahuitzotl</i> *	CR	6	8	4	18
<i>Pseudoeurycea altamontana</i> *	EN	5	8	4	17
<i>Pseudoeurycea amuzga</i> *	DD	6	8	4	18
<i>Pseudoeurycea anitae</i> *	CR	6	8	4	18
<i>Pseudoeurycea aquatica</i> *	CR	6	8	4	18
<i>Pseudoeurycea aurantia</i> *	VU	6	8	4	18
<i>Pseudoeurycea bellii</i> *	VU	5	3	4	12
<i>Pseudoeurycea boneti</i> *	VU	6	7	4	17
<i>Pseudoeurycea brunnata</i>	CR	4	7	4	15
<i>Pseudoeurycea cafetalera</i>	NE	6	7	4	17
<i>Pseudoeurycea cephalica</i> *	NT	5	5	4	14
<i>Pseudoeurycea cochranae</i> *	EN	6	7	4	17
<i>Pseudoeurycea conanti</i> *	EN	5	7	4	16
<i>Pseudoeurycea firscheini</i> *	EN	6	8	4	18
<i>Pseudoeurycea gadovii</i> *	EN	5	4	4	13
<i>Pseudoeurycea galaenae</i> *	NT	6	8	4	18
<i>Pseudoeurycea gigantea</i> *	CR	5	7	4	16
<i>Pseudoeurycea goebeli</i>	CR	4	7	4	15
<i>Pseudoeurycea juarezi</i> *	CR	6	7	4	17
<i>Pseudoeurycea leprosa</i> *	VU	5	7	4	16
<i>Pseudoeurycea lineola</i> *	EN	5	5	4	14
<i>Pseudoeurycea longicauda</i> *	EN	5	8	4	17

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<i>Pseudoeurycea lynchi</i> *	CR	5	8	4	17
<i>Pseudoeurycea maxima</i> *	DD	5	8	4	17
<i>Pseudoeurycea melanomolga</i> *	EN	6	6	4	16
<i>Pseudoeurycea mixcoatl</i> *	DD	6	8	4	17
<i>Pseudoeurycea mixteca</i> *	LC	5	8	4	17
<i>Pseudoeurycea mystax</i> *	EN	6	8	4	18
<i>Pseudoeurycea naucampatepetl</i> *	CR	6	7	4	17
<i>Pseudoeurycea nigromaculata</i> *	CR	5	8	4	17
<i>Pseudoeurycea obesa</i> *	DD	6	8	4	18
<i>Pseudoeurycea orchileucos</i> *	EN	6	8	4	18
<i>Pseudoeurycea orchimelas</i> *	EN	6	7	4	17
<i>Pseudoeurycea papenfussi</i> *	NT	6	7	4	17
<i>Pseudoeurycea praecellens</i> *	CR	6	8	4	18
<i>Pseudoeurycea quetzalanensis</i> *	DD	6	7	4	17
<i>Pseudoeurycea rex</i>	CR	4	4	4	12
<i>Pseudoeurycea robertsi</i> *	CR	6	8	4	18
<i>Pseudoeurycea ruficauda</i> *	DD	6	8	4	18
<i>Pseudoeurycea saltator</i> *	CR	6	8	4	18
<i>Pseudoeurycea scandens</i> *	VU	6	7	4	17
<i>Pseudoeurycea smithi</i> *	CR	5	6	4	15
<i>Pseudoeurycea tenchalli</i> *	EN	6	7	4	17
<i>Pseudoeurycea teotepec</i> *	EN	6	8	4	18
<i>Pseudoeurycea tlahcuiloh</i> *	CR	6	7	4	17
<i>Pseudoeurycea tlilicxiti</i> *	DD	5	8	4	17
<i>Pseudoeurycea unguidentis</i> *	CR	6	7	4	17
<i>Pseudoeurycea werleri</i> *	EN	6	7	4	17
<i>Thorius adelos</i> *	EN	6	8	4	18
<i>Thorius arboreus</i> *	EN	6	8	4	18
<i>Thorius aureus</i> *	CR	6	7	4	17
<i>Thorius boreas</i> *	EN	6	8	4	18
<i>Thorius dubitus</i> *	EN	5	7	4	16
<i>Thorius grandis</i> *	EN	6	5	4	15
<i>Thorius infernalis</i> *	CR	6	8	4	18
<i>Thorius insperatus</i> *	DD	6	8	4	18
<i>Thorius lunaris</i> *	EN	6	8	4	18
<i>Thorius macdougalli</i> *	VU	6	6	4	16
<i>Thorius magnipes</i> *	CR	6	7	4	17
<i>Thorius minutissimus</i> *	CR	6	7	4	17
<i>Thorius minydemus</i> *	CR	6	8	4	18
<i>Thorius munificus</i> *	CR	6	8	4	18
<i>Thorius narismagnus</i> *	CR	6	8	4	18
<i>Thorius narisovalis</i> *	CR	6	7	4	17
<i>Thorius omiltemi</i> *	EN	6	8	4	18
<i>Thorius papaloae</i> *	EN	6	7	4	17
<i>Thorius pennatulus</i> *	CR	5	6	4	15
<i>Thorius pulmonaris</i> *	EN	6	7	4	17
<i>Thorius schmidtii</i> *	EN	6	7	4	17
<i>Thorius smithi</i> *	CR	6	7	4	17
<i>Thorius spilogaster</i> *	CR	6	7	4	17

<i>Thorius troglodytes</i> *	EN	6	6	4	16
Family Salamandridae (1 species)					
<i>Notophthalmus meridionalis</i>	EN	2	8	1	12
Family Sirenidae (2 species)					
<i>Siren intermedia</i>	LC	3	8	1	12
<i>Siren lacertina</i>	LC	3	8	1	12
Order Gymnophiona (2 species)					
Family Dermophiidae (2 species)					
<i>Dermophis mexicanus</i>	VU	4	3	4	11
<i>Dermophis oaxacae</i> *	DD	5	3	4	12



Crotalus tancitarensis. The Tancítaro cross-banded mountain rattlesnake is a small species (maximum recorded total length = 434 mm) known only from the upper elevations (3,220–3,225 m) of Cerro Tancítaro, the highest mountain in Michoacán, Mexico, where it inhabits pine-fir forest (Alvarado and Campbell 2004; Alvarado et al. 2007). Cerro Tancítaro lies in the western portion of the Transverse Volcanic Axis, which extends across Mexico from Jalisco to central Veracruz near the 20°N latitude. Its entire range is located within Parque Nacional Pico de Tancítaro (Campbell 2007), an area under threat from manmade fires, logging, avocado culture, and cattle raising. This attractive rattlesnake was described in 2004 by the senior author and Jonathan A. Campbell, and placed in the *Crotalus intermedius* group of Mexican montane rattlesnakes by Bryson et al. (2011). We calculated its EVS as 19, which is near the upper end of the high vulnerability category (see text for explanation), its IUCN status has been reported as Data Deficient (Campbell 2007), and this species is not listed by SEMARNAT. More information on the natural history and distribution of this species is available, however, which affects its conservation status (especially its IUCN status; Alvarado-Díaz et al. 2007). We consider *C. tancitarensis* one of the pre-eminent flagship reptile species for the state of Michoacán, and for Mexico in general. Photo by Javier Alvarado-Díaz.

Patterns of physiographic distribution and conservation status of the herpetofauna of Michoacán, Mexico

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Abstract.—At their respective levels, the country of Mexico and the state of Michoacán are major centers of herpetofaunal diversity and endemism. Three of us (JAD, ISO, OMA) conducted extensive fieldwork in Michoacán from 1998 to 2011, and recorded 169 herpetofaunal species. With additional species reported in the literature and specimens available in scientific collections, the number of species in Michoacán has grown to 215. We examined the distribution of these species within the framework of the five physiographic provinces within the state, i.e., the Coastal Plain, the Sierra Madre del Sur, the Balsas-Tepalcatepec Depression, the Transverse Volcanic Axis, and the Central Plateau, which briefly are characterized geomorphologically and climatically. The herpetofauna consists of 54 amphibians and 161 reptiles (17.5% of the total for Mexico), classified in 38 families and 96 genera. Almost one-half of Michoacán's herpetofaunal species occur in a single physiographic province, and the percentage of species decreases with an increase in the number of provinces. The province with the most species is the Sierra Madre del Sur, with slightly fewer numbers in the Balsas-Tepalcatepec Depression and the Transverse Volcanic Axis. An intermediate number is found in the Coastal Plain, and the lowest in the Central Plateau province. We constructed a Coefficient of Biogeographic Resemblance matrix and found the greatest degree of herpetofaunal resemblance between the Balsas-Tepalcatepec Depression and the Sierra Madre del Sur. The greatest resemblance of the Coastal Plain herpetofauna is to that of Balsas-Tepalcatepec Depression, that of the Transverse Volcanic Axis to that of the Central Plateau, and vice versa. Of the species limited to one physiographic province, 47 occur only in the Transverse Volcanic Axis, 23 in the Coastal Plain, 15 in the Balsas-Tepalcatepec, 14 in the Sierra Madre del Sur, and one in the Central Plateau. We employed three systems for determining the conservation status of the herpetofauna of Michoacán: SEMARNAT, IUCN, and EVS. Almost one-half of the species in the state are not assessed by the SEMARNAT system, with the remainder allocated to the Endangered (four species), Threatened (31), and Special Protection (79) categories. The IUCN system provides an assessment for 184 of the 212 native species, allocating them to the Critically Endangered (five species), Endangered (10), Vulnerable (12), Near Threatened (four), Least Concern (127), and Data Deficient (26) categories. The EVS system provides a numerical assessment for all of the native non-marine species (four marine species occur in the state), with the values ranging from three to 19. The resulting 208 species were placed in low, medium, and high categories of vulnerability, as follows: low (17 amphibians, 39 reptiles); medium (23 amphibians, 45 reptiles); and high (13 amphibians, 71 reptiles). The EVS system is the only one that provides an assessment for all the species (except for the four marine taxa), as well as the only one that considers the distributional status of Michoacán's herpetofauna (state-level endemic, country-level endemic, and non-endemic). Furthermore, the values indicate that ca. 40% of the state's herpetofauna is categorized at the highest level of environmental vulnerability. Based on these conclusions, we provide recommendations for protecting Michoacán's herpetofauna in perpetuity.

Key words. Amphibians, reptiles, physiographic provinces, conservation status, recommendations

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Resumen.—México es un importante centro de diversidad y endemismo herpetofaunístico y el estado de Michoacán también presenta estas características. Durante el período de 1998–2011, tres de nosotros (JAD, ISO, OMA) conducimos un extenso trabajo de campo en Michoacán, registrando 169 especies de anfibios y reptiles. Con la adición de especies reportadas en la literatura y los registros disponibles en colecciones científicas, el número total de especies de la herpetofauna michoacana es de 215. Examinamos la distribución de estas especies en Michoacán, considerando las cinco provincias fisiográficas representadas en el Estado: la Llanura Costera, la Sierra Madre del Sur, la Depresión del Balsas-Tepalcatepec, el Eje Volcánico Transversal, y la Meseta Central, las que de manera resumida son caracterizadas en base a su geomorfología y clima. La herpetofauna consiste de 54 anfibios y 161 reptiles (17.5% del total de México), clasificadas en 38 familias y 96 géneros. Casi la mitad de las especies de la herpetofauna de Michoacán ocurre en una sola provincia fisiográfica, con un cada vez menor porcentaje de especies a medida que el número de provincias se incrementa. El mayor número de especies se encuentra en la Sierra Madre del Sur, con cifras ligeramente menores en la Depresión del Balsas-Tepalcatepec y el Eje Volcánico Transversal. Un número intermedio de especies se encuentra en la provincia Planicie Costera y el menor número se encuentra en la provincia Meseta Central. Implementamos una matriz del Coeficiente de Semejanza Biogeográfica, la que muestra que el mayor grado de semejanza herpetofaunística se encuentra entre la Depresión del Balsas-Tepalcatepec y la Sierra Madre del Sur. La mayor similitud de la herpetofauna de la Planicie Costera es con la herpetofauna de la Depresión Balsas-Tepalcatepec, la del Eje Volcánico Transversal con la de la Meseta Central y viceversa. De las especies restringidas a una sola provincia fisiográfica, 47 ocurren solamente en el Eje Volcánico Transversal, 23 en la Planicie Costera, 15 en la Depresión del Balsas-Tepalcatepec, 14 en la Sierra Madre del Sur, y una en la Meseta Central. Usamos tres sistemas para determinar el estado de conservación: SEMARNAT, UICN, y EVS. Casi la mitad de las especies de Michoacán no han sido evaluadas por el sistema de SEMARNAT, y las evaluadas han sido asignadas a las categorías de Peligro (cuatro especies), Amenazadas (31), y Protección Especial (79). El sistema de la UICN ha evaluado 184 de las 212 especies nativas de Michoacán, asignadas a las siguientes categorías: Peligro Crítico (cinco especies), En Peligro (10), Vulnerable (12), Casi Amenazado (cuatro), Preocupación Menor (127), y Datos Insuficientes (26). El sistema EVS proporciona una evaluación numérica para todas las especies nativas que no son marinas (cuatro especies marinas ocurren en el estado), con valores de tres a 18. Las 209 especies evaluadas mediante el EVS fueron asignadas a las categorías de baja, media y alta vulnerabilidad de la siguiente manera: baja (17 anfibios, 39 reptiles); media (23 anfibios, 45 reptiles); y alta (13 anfibios, 71 reptiles). El sistema EVS es el único de los tres que proporciona una evaluación de todas las especies (excepto para los cuatro taxa marinos) y el único que considera el estado distribucional de los componentes de la herpetofauna de Michoacán (endémico a nivel estatal, endémico a nivel de país, y no endémico). Además, los valores muestran que cerca del 40% de la herpetofauna del estado se encuentra en la categoría más alta de vulnerabilidad ambiental. En base a estas conclusiones, proponemos recomendaciones para la protección a perpetuidad de la herpetofauna de Michoacán.

Palabras claves. Anfibios, reptiles, provincias fisiográficas, estatus de conservación, recomendaciones

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The publication of On the Origin of Species in 1859 is a recognized watershed in biological science. Perhaps the greatest threat to Western ideology was not the common origin of all beings, as is assumed, but rather the possibility of a common ending: that all beings, humans among them were subjected to the same forces and vulnerabilities.

Chernela 2012: 22.

Introduction

Mesoamerica is one of the principal biodiversity hotspots in the world (Wilson and Johnson 2010), and the country of Mexico comprises about 79% of the land surface of Mesoamerica (CIA World Factbook). The documented amphibian fauna of Mexico currently consists of 379 species, including 237 anurans, 140 salamanders, and two caecilians (Wilson et al. 2013b). Based on this



Incilius pisinnus. The Michoacán toad is a state endemic, with a distribution in the Balsas-Tepalcatepec Depression and the Sierra Madre del Sur. Its EVS was estimated as 15, which is unusually high for a bufonid anuran, its IUCN ranking has been judged as Data Deficient, and a SEMARNAT status has not been provided. This individual is from Apatzingán, Michoacán.

Photo by Oscar Medina-Aguilar.



Eleutherodactylus rufescens. The blunt-toed chirping frog is endemic to the Sierra de Coalcomán region of the Sierra Madre del Sur. Its EVS has been assessed as 17, placing this species in the middle of the high vulnerability category, this frog is considered as Critically Endangered by IUCN, and as a Special Protection species by SEMARNAT. This individual was found at Dos Aguas in the Sierra de Coalcomán (Sierra Madre del Sur) in Michoacán. *Photo by Oscar Medina-Aguilar.*

figure, Mexico is the country with the 5th largest number of amphibian species in the world (Llorente-Bousquets and Ocegueda 2008; Stuart et al. 2010a), after Brazil, Colombia, Ecuador, and Peru. The country also is inhabited by 849 species of reptiles, including 798 squamates, 48 turtles, and three crocodylians (Wilson et al. 2013a), which globally is the second largest reptile fauna (Llorente-Bousquets and Ocegueda 2008), after Australia. The total number of 1,227 species makes the Mexican herpetofauna the second largest in the world (Llorente-Bousquets and Ocegueda 2008), comprising 7.3% of the global herpetofauna (7,044 amphibian species, according to the Amphibian Species of the World website, accessed 21 February 2013, and 9,766 reptile species, according to the Reptile Database website, also accessed 21 February 2013, for a total of 16,810).

Beyond its highly significant herpetofaunal diversity, Mexico also contains an amazing amount of endemism. Currently, 254 of 379 (67.0%) of the known amphibian species and 480 of 849 (56.5%) of the known reptile species are endemic (Wilson et al. 2013a,b). The combined figure for both groups is 734 species (59.8%), a percentage 2.4 times as high as the next highest rate of endemism for the Central American countries (24.8% for Honduras; Townsend and Wilson 2010).

Michoacán (the formal name is Michoacán de Ocampo) is the 16th largest state in Mexico, with an area of 58,599 km² (www.en.wikipedia.org/wiki/List_of_Mexican_states_by_area), which comprises about 3.0% of the

country's land surface. The state is located in southwestern Mexico between latitudes 20°23'44" and 18°09'49" N and longitudes 100°04'48" and 103°44'20" W, and is bounded to the northwest by Colima and Jalisco, to the north by Guanajuato and Querétaro, to the east by México, and to the southeast by Guerrero. Michoacán is physiographically and vegetationally diverse, inasmuch as elevations range from sea level to 3,840 m (at the top of Volcán Tancítaro). The state encompasses a portion of the Pacific coastal plain, a long stretch of the Balsas-Tepalcatepec Depression, a segment of the Sierra Madre del Sur called the Sierra de Coalcomán, and a significant portion of the Transverse Volcanic Axis.

Mexico is known for its high level of herpetofaunal endemism, but compared with the country the herpetofauna of Michoacán is several percentage points higher, with a number of the country endemics limited in distribution to the state (see below). Any attempt to assess the conservation status of a herpetofaunal group depends on an accurate accounting of the distribution and composition of the species involved. Thus, our objectives with this study are to update the list of amphibians and reptiles in Michoacán, to discuss their distribution among the physiographic provinces, and to use these data to gauge the conservation status of the entire herpetofauna using various measures. Finally, based on our conservation assessment, we provide recommendations to enhance current efforts to protect the state's amphibians and reptiles.



Diaglena spatulata. The shovel-headed treefrog is distributed along the Pacific coastal lowlands from Sinaloa to Oaxaca, and thus is a Mexican endemic hyloid anuran. In Michoacán, it occurs in the Balsas-Tepalcatepec Depression and along the Coastal Plain. Its EVS was gauged as 13, placing it at the upper end of the medium vulnerability category, IUCN has assessed this anuran as Least Concern, and it is not listed by SEMARNAT. This individual was photographed at the Reserva de la Biosfera Chamela-Cuixmala on the coast of Jalisco. Photo by Oscar Medina-Aguilar.

Materials and Methods

1. Sampling procedures

From 1998 to 2011, three of us (JAD, ISO, OMA) conducted fieldwork in 280 localities (58 municipalities) of Michoacán, representing all of the state's physiographic provinces, with significant attention paid to poorly sampled areas, as part of the “Diversidad Herpetofaunística del Estado de Michoacán” project undertaken by personnel from the Laboratorio de Herpetología of the Instituto de Investigaciones sobre los Recursos Naturales (INIRENA) of the Universidad Michoacana de San Nicolás de Hidalgo (UMSNH). Importantly, due to unsafe conditions in certain parts of the state in recent years, large areas have not been explored. During each visit to the sampling sites, we used visual encounter surveys (Crump and Scott 1994) to locate amphibians and reptiles during the day and at night. This work was conducted under scientific collecting permits (DGVVS/FAUT-0113), and used the collection techniques described by Casas et al. (1991). In cases where we could not identify individuals in the field, they were sacrificed and subsequently deposited in the herpetological collections of INIRENA-UMSNH. We identified specimens by using taxonomic keys and other information in Smith and Taylor (1945, 1948, 1950), Duellman (1961, 1965, 2001), Casas-Andréu and McCoy (1979), Ramírez-Bautista (1994), Flores-Villela et al. (1995), and Huacuz (1995), and updated scientific names by using Flores-Villela and Canseco-Márquez (2004), Faivovich et al. (2005), Wilson and Johnson (2010), and Wilson et al. (2013a,b).

2. Updating the herpetofaunal list

In addition to the specimens recorded during the fieldwork, the list of species was augmented using material donated by others. We also used records from the Colección Nacional de Anfibios y Reptiles-UNAM (CNAR), the California Academy of Sciences (CAS), the University of Colorado Museum of Natural History, Herpetology Collection (CUMNH), the Museum of Natural Sciences, Louisiana State University (LSUMZ), the Field Museum of Natural History (FMNH), and the Royal Ontario Museum (ROM). Additionally, we included records for Michoacán from the Catálogo de la Biodiversidad en Michoacán (SEDUE [Secretaría de Desarrollo Urbano y Ecología], UMSNH 2000), la Biodiversidad en Michoacán Estudio de Estado (Villaseñor 2005), various distribution notes published in *Herpetological Review* and otherwise posted at the IUCN Red List website, as well as data presented by Flores-Villela and Canseco-Márquez (2004), Vargas-Santamaría and Flores-Villela (2006), González-Hernández and Garza-Castro (2006), Medina-Aguilar et al. (2011), and Torres (2011). We follow the taxonomy used in Wilson (2013a, b), with the exception

of the deletion of the nominal species *Anolis schmidti*, which recently was synonymized by Nieto et al. (2013).

3. Systems for determining conservation status

We used the following three systems to determine the conservation status of the 212 native species of amphibians and reptiles in Michoacán: SEMARNAT, IUCN, and EVS. The SEMARNAT system, established by the Secretaría de Medio Ambiente y Recursos Naturales, employs three categories—Endangered (P), Threatened (A), and Subject to Special Protection (Pr). The results of the application of this system are reported in the NORMA Oficial Mexicana NOM-059-SEMARNAT-2010 (www.semarnat.gob.mx). For species not assessed by this system, we use the designation “No Status.”

The IUCN system is utilized widely to assess the conservation status of species on a global basis. The categories used are explained in the document *IUCN Red List of Categories and Criteria* (2010), and include Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE). The categories Critically Endangered, Endangered, and Vulnerable collectively are termed “threat categories,” to distinguish them from the other six.

The EVS system was developed initially for use in Honduras by Wilson and McCranie (2004), and subsequently was used in several chapters on Central American countries in Wilson et al. (2010). Wilson et al. (2013a,b) modified this system and explained its use for the amphibians and reptiles of Mexico, and we follow their prescriptions. The EVS measure is not designed for use with marine species (e.g., marine turtles and sea snakes), and generally is not applied to non-native species.

Physiography and Climate

1. Physiographic provinces

Based on geological history, morphology, structure, hydrography, and soils, five physiographic provinces can be recognized within the state of Michoacán, including the Pacific Coastal Plain, the Sierra Madre del Sur, the Balsas-Tepalcatepec Depression, the Transverse Volcanic Axis, and the Central Plateau (Fig. 1). The Coastal Plain province comprises a narrow strip of land between the Pacific Ocean and the Sierra Madre del Sur, and consists of small alluvial plains extending from the mouth of the Río Balsas to the east and the Río Coahuayana to the west. The Sierra Madre del Sur (Sierra de Coalcomán) lies between the Coastal Plain and the Balsas-Tepalcatepec Depression, extends for over 100 km in a northwest-southeast direction, and contains elevations reaching about 2,200 m. The Balsas-Tepalcatepec Depression

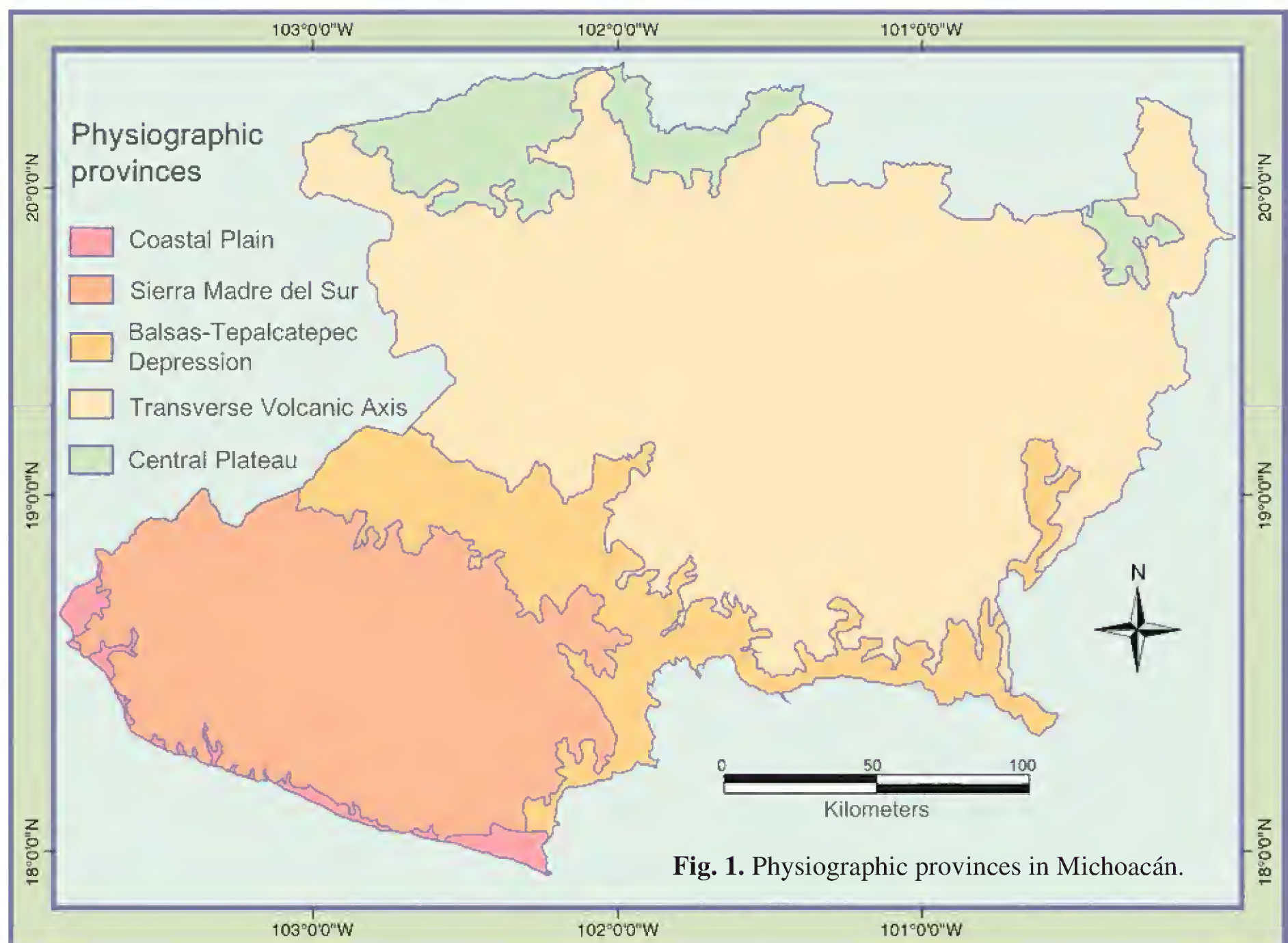


Fig. 1. Physiographic provinces in Michoacán.

is located between the Sierra Madre del Sur to the southwest and the Transverse Volcanic Axis to the northeast. This intermontane area is a broad structural basin that lies at elevations ranging from 200 to 700 m. As noted by Duellman (1961:10), “the western part of this basin... is the valley of the Río Tepalcatepec, a major tributary of the Río Balsas. The eastern part of the basin is the valley of the Río Balsas.” The Transverse Volcanic Axis is located to the south of the Central Plateau and crosses Mexico at about the 20th parallel. The region is composed of volcanic ejecta and is volcanically active. This area is home to Mexico’s highest mountains, such as Pico de Orizaba (5,636 m) and Popocatepetl (5,426 m), which in Michoacán is represented by Pico de Tancítaro, with an elevation of 3,850 m. In addition, several endorheic lakes are located in this province, including Pátzcuaro, Zirahuén, and Cuitzeo. The Central Plateau is a vast tableland bordered on the south by the Transverse Volcanic Axis, on the west by the Sierra Madre Occidental, on the east by the Sierra Madre Oriental, and on the north by the Río Bravo (Rio Grande). Elevations in this province range from 1,100 m in the northern portion of the country to 2,000 m. In Michoacán, this province is represented by a relatively small area (3,905 km²) along the northern border of the state; the Río Lerma flows from it, and empties into the Pacific Ocean (Duellman 1961).

2. Climate

Given its location in the tropical region of Mexico, south of the Tropic of Cancer, temperatures in Michoacán vary as a consequence of differences in elevation and the effects of prevailing winds. To illustrate variation in ambient temperatures in the state, we extracted data for one locality from each of the five physiographic provinces from the Servicio Meteorológico Nacional, Michoacán, and placed them in Table 1. These data are organized in the table from top to bottom based on the elevation of the localities (from low to high). As expected, a decrease in the mean annual temperature occurs from lower to higher elevations. The same pattern is seen for annual minimum and maximum temperatures, except for the Coastal Plain compared to the Balsas-Tepalcatepec Depression (33.0 vs. 34.4 °C).

As expected in the tropics, relatively little temperature variation occurs throughout the year. The differences between the low and high mean monthly temperatures (in °C) for the localities in the five physiographic provinces are as follows: Coastal Plain (Lázaro Cárdenas, 50 m) = 1.9; Balsas-Tepalcatepec Depression (Apatzingán, 320 m) = 5.5; Sierra Madre del Sur (Coalcomán, 1,100 m) = 5.2; Central Plateau (Morelia, 1,915 m) = 5.9; and Transverse Volcanic Axis (Pátzcuaro, 2,035 m) = 6.6.

The lowest mean monthly temperatures are for January, and the highest for May or June. Essentially the same pattern occurs with minimum and maximum monthly temperatures, except for minor departures in a few areas (Table 1).

The highest mean monthly temperature (34.4 °C) is at Apatzingán in the Balsas-Tepalcatepec Depression. Duellman (1961) stated that the highest mean annual temperatures (29.3 °C) in this depression have been recorded at Churumuco (251 m), as reported by Contreras (1942). More recent data at the Servicio Meteorológico Nacional website for Michoacán indicates that the highest daily temperature of 46 °C was recorded at this locality on 9 April 1982. At the other extreme are

temperatures on the peak of Volcán Tancítaro, where the mean annual temperature is less than 10 °C and it snows during the winter.

In tropical locales, heavy or light precipitation typically occurs during the rainy and dry seasons, respectively. In Michoacán, the rainy season extends from June to October, when 80% or more of the annual precipitation is deposited. As with temperature data, we extracted information on mean annual precipitation and variation in monthly precipitation recorded at one locality for each of the five physiographic provinces, and placed the data in Table 2. The results demonstrate that at each locality the highest amount of precipitation occurs from June to October. The percentage of annual precipitation

Table 1. Monthly minimum, mean (in parentheses), maximum, and annual temperature data (in °C) for the physiographic provinces of Michoacán, Mexico. Localities and their elevation for each of the provinces are as follows: Coastal Plain (Lázaro Cárdenas, 50 m); Balsas-Tepalcatepec Depression (Apatzingán, 320 m); Sierra Madre del Sur (Coalcomán de Vázquez Pallares, 1,100 m); Central Plateau (Morelia, 1,915 m); Transverse Volcanic Axis (Pátzcuaro, 2,035 m). Data (1971–2000) from the Sistema Meteorológico Nacional, Michoacán (smn.cna.gob.mx/index).

Physiographic Province	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Coastal Plain	20.6 (26.6) 32.6	20.6 (26.8) 33.1	20.8 (27.0) 33.2	21.2 (27.3) 33.5	22.8 (28.3) 33.8	23.9 (28.5) 33.1	23.4 (28.0) 32.7	23.7 (28.1) 32.6	23.3 (27.7) 32.0	23.5 (28.1) 32.6	22.7 (27.9) 33.2	21.1 (27.1) 33.2	22.3 (27.6) 33.0
Balsas-Tepalcatepec Depression	16.7 (24.6) 32.5	17.6 (25.9) 34.1	19.1 (27.7) 36.3	20.7 (29.2) 37.6	22.3 (30.3) 38.3	22.7 (29.1) 35.6	21.6 (27.3) 33.1	21.6 (27.3) 33.1	21.7 (27.3) 33.0	21.5 (27.7) 33.8	19.5 (26.4) 33.3	17.7 (25.1) 32.5	20.2 (27.3) 34.4
Sierra Madre del Sur	10.2 (19.9) 29.7	10.7 (20.8) 30.9	11.6 (22.1) 32.7	12.3 (23.5) 34.6	14.3 (24.8) 35.3	17.9 (25.1) 32.4	18.2 (24.1) 30.1	17.4 (23.8) 30.2	17.7 (23.8) 30.0	16.7 (23.7) 30.8	13.9 (22.2) 30.4	11.9 (21.0) 30.0	14.4 (22.9) 31.4
Central Plateau	6.8 (15.8) 24.7	7.6 (17.0) 26.4	9.6 (19.0) 28.4	11.1 (20.4) 29.7	12.6 (21.7) 30.9	13.3 (21.2) 29.1	12.8 (19.6) 26.5	13.1 (19.8) 26.4	12.9 (19.4) 26.0	11.3 (18.7) 26.1	9.3 (17.7) 26.2	7.3 (16.4) 25.5	10.6 (18.9) 27.2
Transverse Volcanic Axis	3.3 (12.9) 22.5	4.0 (14.1) 24.1	5.4 (16.0) 26.6	7.3 (17.8) 28.2	9.4 (19.1) 28.7	12.5 (19.5) 26.4	12.0 (18.0) 23.9	11.9 (18.0) 24.1	11.5 (17.7) 23.9	9.2 (16.7) 24.1	5.9 (14.8) 23.7	4.3 (13.4) 22.6	8.1 (16.5) 24.9

Table 2. Monthly and annual precipitation data (in mm.) for the physiographic provinces of Michoacán, Mexico. Localities and their elevation for each of the provinces are as follows: Coastal Plain (Lázaro Cárdenas, 50 m); Sierra Madre del Sur (Coalcomán de Vázquez Pallares, 1,100 m); Balsas-Tepalcatepec Depression (Apatzingán, 320 m); Transverse Volcanic Axis (Pátzcuaro, 2,035 m); Central Plateau (Morelia, 1,915 m). The shaded area indicates the months of the rainy season. Data taken from Servicio Meteorológico Nacional, Michoacán (smn.cna.gob.mx/index).

Physiographic Province	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Coastal Plain	7.5	0.4	1.0	0.0	17.0	240.4	269.0	257.0	374.2	150.1	23.7	34.0	1,374.3
Balsas-Tepalcatepec Depression	19.8	22.0	9.0	2.5	24.1	138.0	167.9	160.8	133.6	78.8	36.9	15.3	808.7
Sierra Madre del Sur	33.7	42.8	24.8	7.8	37.2	272.2	284.1	258.0	225.7	166.8	93.0	42.1	1,488.2
Central Plateau	15.8	5.6	7.5	9.9	37.9	146.5	166.1	167.8	131.6	51.6	10.4	4.2	754.9
Transverse Volcanic Axis	27.1	5.0	5.1	9.7	37.8	150.3	219.6	204.1	157.9	71.2	17.6	13.4	918.8

during this period ranges from 81.1% at Coalcomán in the Sierra Madre del Sur to 93.9% at Lázaro Cárdenas on the Coastal Plain (mean 86.9%). Generally, the driest month is April (except on the Central Plateau, where it is December) and the wettest month is July (except on the Central Plateau, where it is August). Annual precipitation is lowest on the Central Plateau, with 754.9 mm for the capital city of Morelia, and highest at Coalcomán in the Sierra Madre del Sur, with 1,488.2 mm (Table 2).

Composition of the Herpetofauna

Field surveys and a review of the published literature and databases yielded a total of 215 species of amphibians and reptiles for the state of Michoacán (54 amphibians, 161 reptiles). Of the amphibians, 44 are anurans (81.1%, including the non-native *Lithobates catesbeianus*), nine are salamanders (17.0%), and one is a caecilian (1.9%). Of the 161 reptiles, 153 are squamates (95.0%, including the non-native *Hemidactylus frenatus* and *Ramphotyphlops braminus*), seven are turtles (4.4%), and one is a crocodylian (0.6%). The number of species occurring in Michoacán is 17.5% of the total for the Mexican herpetofauna (1,227 species; Wilson et al. 2013a,b; Table 3).

Table 3. Composition of the amphibians and reptiles of Mexico and the state of Michoacán. In each column, the number to the left is that indicated in Wilson et al. (2013a,b) for the country of Mexico; the number to the right is that recorded in this study for the state of Michoacán. These numbers include the marine and non-native taxa.

Taxa	Families	Genera	Species
Anura	11/9	35/19	237/44
Caudata	4/2	15/2	139/9
Gymnophiona	1/1	1/1	2/1
Subtotals	16/12	51/22	378/54
Squamata	31/21	139/68	798/153
Testudines	9/4	18/5	48/7
Crocodylia	2/1	2/1	3/1
Subtotals	42/26	159/74	849/161
Totals	58/38	210/96	1,227/215

1. Families

The herpetofauna of Michoacán (215 species) is classified in 38 families (65.5% of the number in Mexico), with the 54 species of amphibians in 12 of the 16 families known from the country (75.0%; Wilson et al. 2013a, b; Table 3). About one-half of the amphibian species are classified in one of three families (Hylidae, Ranidae, and

Ambystomatidae). The 161 species of reptiles are classified in 26 families (including the family Gekkonidae, occupied by a single non-native species, *H. frenatus*, and the family Typhlopidae, occupied by a single non-native species, *R. braminus*), 61.9% of the 42 families found in Mexico (Wilson et al. 2013a; Table 3). One-half of the species of reptiles in the state are classified in one of three families (Phrynosomatidae, Colubridae, and Dipsadidae).

2. Genera

The herpetofauna of Michoacán is represented by 96 genera (45.7% of the 210 known from Mexico; Wilson et al. 2013a,b), with the amphibians composed of 22 genera (43.1% of the 51 known from the country). The reptiles consist of 74 genera (46.5% of the country total of 159). The largest amphibian genera are *Incilius* (four species), *Craugastor* (five), *Eleutherodactylus* (five), *Lithobates* (11), and *Ambystoma* (seven). Together, these 32 species comprise 59.3% of the amphibians known from the state (Table 3). The most sizable reptilian genera are *Sceloporus* (16), *Geophis* (nine), *Thamnophis* (nine), *Crotalus* (eight), *Aspidoscelis* (seven), *Phyllodactylus* (five), *Plestiodon* (five), *Coniophanes* (five), and *Leptodeira* (five). These 69 species constitute 42.9% of the reptiles known from the state (Table 3).

3. Species

Mexico is home to 378 amphibian species, of which 54 (14.3%) occur in Michoacán (Table 3). Anurans are better represented in the state (18.6% of 237 Mexican species) than salamanders (6.5% of 139). Only two caecilian species are known from Mexico, and one occurs in Michoacán (50.0%). Mexico also is inhabited by 849 reptile species, of which 161 (19.0%) are found in Michoacán. Squamates are somewhat better represented in the state (19.2% of 798) than turtles (14.6% of 48). Only three crocodylian species occur in Mexico, and one is found in Michoacán (Table 3).

Patterns of Physiographic Distribution

We recognize five physiographic provinces in Michoacán (Fig. 1), and their herpetofaunal distribution is indicated in Table 4 and summarized by family in Table 5.

Of the 215 species recorded from the state, 100 (46.5%, 24 amphibians, 76 reptiles) are limited in distribution to a single physiographic province. In addition, 64 (29.8%, 15 amphibians, 49 reptiles) are known from two provinces, 37 (17.2%, eight amphibians, 29 reptiles) from three, 11 (5.1%, seven amphibians, four reptiles) from four, and only three (1.4%, 0 amphibians, three reptiles) from all five provinces (Table 4). In both amphibians and reptiles, the number of species steadily drops from the lowest to the highest occupancy figures. This distributional feature is significant to conservation

efforts, inasmuch as the more restricted their distribution the more difficult it will be to provide species with effective protective measures. This feature is obvious when examining the mean occupancy figure, which is 2.0 for amphibians and 1.8 for reptiles, indicating that on average both groups occupy two or slightly fewer physiographic provinces. The three most broadly distributed species (i.e., occurring in all five provinces) all are reptiles and include the anole *Anolis nebulosus*, the whipsnake *Masticophis mentovarius*, and the mud turtle *Kinosternon integrum* (Table 4). The most broadly distributed amphibians all are anurans and include the following seven species: the toad *Rhinella marina*, the chirping frog *Eleutherodactylus nitidus*, the treefrogs

Exerodonta smaragdina and *Hyla arenicolor*, the white-lipped frog *Leptodactylus fragilis*, the sheep frog *Hypopachus variolosus*, and the leopard frog *Lithobates neovolcanicus* (Table 4).

Similar numbers of species have been recorded from the Balsas-Tepalcatepec Depression, the Sierra Madre del Sur, and the Transverse Volcanic Axis. A smaller number occupies the Coastal Plain and the smallest number is found on the Central Plateau. The distinction between the species numbers in the higher-species areas (Balsas-Tepalcatepec Depression, Sierra Madre del Sur, and the Transverse Volcanic Axis) and the lower-species areas (Coastal Plain and Central Plateau) is more marked for amphibians than for reptiles (Table 5).

Table 4. Distribution of the native and non-native amphibian and reptiles of Michoacán, Mexico, by physiographic province.

Taxa	Physiographic Provinces				
	Coastal Plain (COP)	Balsas-Tepalcatepec Depression (BTD)	Sierra Madre del Sur (SMS)	Transverse Volcanic Axis (TVA)	Central Plateau (CEP)
Amphibia (54 species)					
Anura (44 species)					
Bufonidae (6 species)					
<i>Anaxyrus compactilis</i>				+	+
<i>Incilius marmoreus</i>	+	+	+		
<i>Incilius occidentalis</i>			+	+	
<i>Incilius perplexus</i>		+	+		
<i>Incilius pisinnus</i>		+	+		
<i>Rhinella marina</i>	+	+	+		+
Craugastoridae (5 species)					
<i>Craugastor augusti</i>			+	+	
<i>Craugastor hobartsmithi</i>				+	
<i>Craugastor occidentalis</i>				+	
<i>Craugastor pygmaeus</i>		+	+	+	
<i>Craugastor vocalis</i>		+	+	+	
Eleutherodactylidae (5 species)					
<i>Eleutherodactylus angustidigitorum</i>				+	
<i>Eleutherodactylus maurus</i>		+			
<i>Eleutherodactylus modestus</i>			+		
<i>Eleutherodactylus nitidus</i>		+	+	+	+
<i>Eleutherodactylus rufescens</i>			+		
Hylidae (11 species)					
<i>Agalychnis dacnicolor</i>	+	+	+		
<i>Diaglena spatulata</i>	+	+			
<i>Exerodonta smaragdina</i>		+	+	+	+
<i>Hyla arenicolor</i>		+	+	+	+
<i>Hyla eximia</i>				+	+

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<i>Hyla plicata</i>				+	
<i>Plectrohyla bistincta</i>			+	+	
<i>Smilisca baudinii</i>	+	+	+		
<i>Smilisca fodiens</i>		+			+
<i>Tlalocohyla smithii</i>	+	+	+		
<i>Trachycephalus typhonius</i>	+				
Leptodactylidae (2 species)					
<i>Leptodactylus fragilis</i>	+	+	+	+	
<i>Leptodactylus melanonotus</i>	+	+	+		
Microhylidae (2 species)					
<i>Hypopachus ustus</i>	+				
<i>Hypopachus variolosus</i>		+	+	+	+
Ranidae (11 species)					
<i>Lithobates berlandieri</i>		+			
<i>Lithobates catesbeianus</i>				+	
<i>Lithobates dunni</i>				+	
<i>Lithobates forreri</i>		+	+		
<i>Lithobates magnaocularis</i>		+			
<i>Lithobates megapoda</i>				+	+
<i>Lithobates montezumae</i>				+	+
<i>Lithobates neovolcanicus</i>		+	+	+	+
<i>Lithobates pustulosus</i>		+	+	+	
<i>Lithobates spectabilis</i>				+	
<i>Lithobates zweifeli</i>		+	+		
Rhinophrynidae (1 species)					
<i>Rhinophrynus dorsalis</i>		+			
Scaphiopodidae (1 species)					
<i>Spea multiplicata</i>				+	+
Caudata (9 species)					
Ambystomatidae (6 species)					
<i>Ambystoma amblycephalum</i>				+	
<i>Ambystoma andersoni</i>				+	
<i>Ambystoma dumerilii</i>				+	
<i>Ambystoma ordinarium</i>				+	
<i>Ambystoma rivulare</i>				+	
<i>Ambystoma velasci</i>				+	
Plethodontidae (3 species)					
<i>Pseudoeurycea bellii</i>				+	
<i>Pseudoeurycea leprosa</i>				+	
<i>Pseudoeurycea longicauda</i>				+	
Gymnophiona (1 species)					
Caeciliidae (1 species)					
<i>Dermophis oaxacae</i>	+			+	
Reptilia (161 species)					
Crocodylia (1 species)					
Crocodylidae (1 species)					
<i>Crocodylus acutus</i>	+				

Squamata (153 species)					
Bipedidae (1 species)					
<i>Bipes canaliculatus</i>		+			
Anguidae (6 species)					
<i>Abronia deppii</i>				+	
<i>Barisia imbricata</i>				+	
<i>Barisia jonesi</i>			+		
<i>Barisia rudicollis</i>				+	
<i>Elgaria kingii</i>			+		
<i>Gerrhonotus liocephalus</i>				+	
Corytophanidae (1 species)					
<i>Basiliscus vittatus</i>	+	+	+		
Dactyloidae (2 species)					
<i>Anolis dunni</i>		+	+		
<i>Anolis nebulosus</i>	+	+	+	+	+
Eublepharidae (1 species)					
<i>Coleonyx elegans</i>	+	+			
Gekkonidae (1 species)					
<i>Hemidactylus frenatus</i>	+	+	+		
Helodermatidae (1 species)					
<i>Heloderma horridum</i>	+	+	+		
Iguanidae (3 species)					
<i>Ctenosaura clarki</i>		+			
<i>Ctenosaura pectinata</i>	+	+	+		
<i>Iguana iguana</i>	+	+	+		
Mabuyidae (1 species)					
<i>Marisora brachypoda</i>	+	+			
Phrynosomatidae (20 species)					
<i>Phrynosoma asio</i>		+	+		
<i>Phrynosoma orbiculare</i>				+	
<i>Sceloporus aeneus</i>				+	
<i>Sceloporus asper</i>		+	+	+	
<i>Sceloporus bulleri</i>			+		
<i>Sceloporus dugesii</i>				+	+
<i>Sceloporus gadoviae</i>		+	+		
<i>Sceloporus grammicus</i>				+	
<i>Sceloporus heterolepis</i>			+	+	
<i>Sceloporus horridus</i>	+	+	+	+	
<i>Sceloporus insignis</i>			+		
<i>Sceloporus melanorhinus</i>	+	+	+		
<i>Sceloporus pyrocephalus</i>	+	+	+		
<i>Sceloporus scalaris</i>				+	+
<i>Sceloporus siniferus</i>	+		+		
<i>Sceloporus spinosus</i>				+	+
<i>Sceloporus torquatus</i>				+	+
<i>Sceloporus utiformis</i>	+	+	+	+	
<i>Urosaurus bicarinatus</i>	+	+	+	+	

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<i>Urosaurus gadovi</i>		+	+		
Phyllodactylidae (5 species)					
<i>Phyllodactylus davisi</i>	+				
<i>Phyllodactylus duellmani</i>		+	+		
<i>Phyllodactylus homolepidurus</i>	+				
<i>Phyllodactylus lanei</i>	+	+	+	+	
<i>Phyllodactylus paucituberculatus</i>		+			
Scincidae (6 species)					
<i>Mesoscincus altamirani</i>		+	+		
<i>Plestiodon colimensis</i>	+		+		
<i>Plestiodon copei</i>				+	
<i>Plestiodon dugesii</i>				+	
<i>Plestiodon indubitus</i>			+	+	
<i>Plestiodon parvulus</i>	+				
Sphenomorphidae (1 species)					
<i>Scincella assata</i>	+	+	+		
Teiidae (8 species)					
<i>Aspidoscelis calidipes</i>		+	+		
<i>Aspidoscelis communis</i>	+	+	+		
<i>Aspidoscelis costata</i>		+	+		
<i>Aspidoscelis deppei</i>	+	+	+		
<i>Aspidoscelis gularis</i>				+	+
<i>Aspidoscelis lineatissima</i>	+	+	+		
<i>Aspidoscelis sacki</i>		+			
<i>Holcosus undulatus</i>	+	+	+		
Xantusiidae (1 species)					
<i>Lepidophyma tarascae</i>	+	+			
Boidae (1 species)					
<i>Boa constrictor</i>	+	+	+		
Colubridae (28 species)					
<i>Conopsis biserialis</i>				+	
<i>Conopsis lineatus</i>				+	+
<i>Conopsis nasus</i>				+	
<i>Drymarchon melanurus</i>	+	+	+		
<i>Drymobius margaritiferus</i>	+	+	+		
<i>Geagras redimitus</i>	+				
<i>Gyalopion canum</i>				+	
<i>Lampropeltis ruthveni</i>				+	
<i>Lampropeltis triangulum</i>				+	
<i>Leptophis diplotropis</i>	+	+	+		
<i>Masticophis flagellum</i>		+		+	
<i>Masticophis mentovarius</i>	+	+	+	+	+
<i>Masticophis taeniatus</i>				+	+
<i>Mastigodryas melanolomus</i>	+		+		
<i>Oxybelis aeneus</i>	+	+	+		
<i>Pituophis deppei</i>				+	+

<i>Pituophis lineaticollis</i>			+	+	
<i>Pseudoficimia frontalis</i>	+	+	+		
<i>Salvadora bairdi</i>				+	+
<i>Salvadora mexicana</i>		+	+		
<i>Senticolis triaspis</i>		+	+		
<i>Sonora michoacanensis</i>		+	+		
<i>Symphimus leucostomus</i>	+				
<i>Tantilla bocourti</i>				+	
<i>Tantilla calamarina</i>	+	+	+		
<i>Tantilla cascadae</i>				+	
<i>Trimorphodon biscutatus</i>	+	+	+		
<i>Trimorphodon tau</i>		+		+	+
Dipsadidae (33 species)					
<i>Coniophanes fissidens</i>		+	+		
<i>Coniophanes lateritius</i>		+	+		
<i>Coniophanes michoacanensis</i>	+				
<i>Coniophanes piceivittis</i>	+				
<i>Coniophanes sarae</i>			+		
<i>Diadophis punctatus</i>				+	
<i>Dipsas gaigeae</i>			+		
<i>Enulius flavitorques</i>		+	+		
<i>Enulius oligostichus</i>	+				
<i>Geophis bicolor</i>				+	
<i>Geophis dugesii</i>				+	
<i>Geophis incomptus</i>			+		
<i>Geophis maculiferus</i>				+	
<i>Geophis nigrocinctus</i>			+		
<i>Geophis petersii</i>			+	+	
<i>Geophis pyburni</i>			+		
<i>Geophis sieboldi</i>			+		
<i>Geophis tarascae</i>				+	
<i>Hypsiglena torquata</i>		+	+		
<i>Imantodes gemmistratus</i>		+			
<i>Leptodeira maculata</i>	+	+	+		
<i>Leptodeira nigrofasciata</i>	+				
<i>Leptodeira septentrionalis</i>		+			
<i>Leptodeira splendida</i>		+	+	+	
<i>Leptodeira uribei</i>	+				
<i>Pseudoleptodeira latifasciata</i>		+	+		
<i>Rhadinaea hesperia</i>		+	+		
<i>Rhadinaea laureata</i>				+	
<i>Rhadinaea taeniata</i>				+	
<i>Sibon nebulata</i>	+		+		
<i>Tropidodipsas annulifera</i>			+		
<i>Tropidodipsas fasciata</i>			+		
<i>Tropidodipsas philippii</i>	+		+		

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Elapidae (4 species)					
<i>Micrurus distans</i>		+	+		
<i>Micrurus laticollaris</i>		+			
<i>Micrurus tener</i>				+	
<i>Pelamis platura</i>	+				
Leptotyphlopidae (4 species)					
<i>Epictia goudotii</i>		+	+		
<i>Rena bressoni</i>		+			
<i>Rena humilis</i>		+			
<i>Rena maxima</i>		+			
Loxocemidae (1 species)					
<i>Loxocemus bicolor</i>		+	+		
Natricidae (11 species)					
<i>Adelophis copei</i>					+
<i>Storeria storerioides</i>			+	+	
<i>Thamnophis cyrtopsis</i>			+	+	
<i>Thamnophis eques</i>				+	+
<i>Thamnophis melanogaster</i>				+	
<i>Thamnophis postremus</i>		+			
<i>Thamnophis proximus</i>	+				
<i>Thamnophis pulchrilatus</i>				+	
<i>Thamnophis scalaris</i>				+	
<i>Thamnophis scaliger</i>				+	+
<i>Thamnophis validus</i>	+				
Typhlopidae (1 species)					
<i>Ramphotyphlops braminus</i>		+	+	+	
Viperidae (10 species)					
<i>Agkistrodon bilineatus</i>	+	+	+		
<i>Crotalus aquilus</i>				+	
<i>Crotalus basiliscus</i>	+	+	+		
<i>Crotalus culminatus</i>		+			
<i>Crotalus molossus</i>				+	
<i>Crotalus polystictus</i>				+	
<i>Crotalus pusillus</i>			+	+	
<i>Crotalus tancitarensis</i>				+	
<i>Crotalus triseriatus</i>				+	
<i>Porthidium hespere</i>	+				
Xenodontidae (2 species)					
<i>Conophis vittatus</i>	+	+	+		
<i>Manolepis putnami</i>	+	+			
Testudines (7 species)					
Cheloniidae (2 species)					
<i>Chelonia mydas</i>	+				
<i>Lepidochelys olivacea</i>	+				
Dermochelyidae (1 species)					
<i>Dermochelys coriacea</i>	+				

Geoemydidae (2 species)					
<i>Rhinoclemmys pulcherrima</i>	+				
<i>Rhinoclemmys rubida</i>	+	+	+		
Kinosternidae (2 species)					
<i>Kinosternon hirtipes</i>				+	+
<i>Kinosternon integrum</i>	+	+	+	+	+

Table 5. Summary of the distributional occurrence of families of amphibians and reptiles in Michoacán by physiographic province.

Families	Number of Species	Distributional Occurrence				
		Coastal Plain (COP)	Balsas-Tepalcatepec Depression (BTD)	Sierra Madre del Sur (SMS)	Transverse Volcanic Axis (TVA)	Central Plateau (CEP)
Bufonidae	6	2	4	5	2	2
Craugastoridae	5	—	2	3	5	—
Eleutherodactylidae	5	—	2	3	2	1
Hylidae	11	5	7	6	5	4
Leptodactylidae	2	2	2	2	1	—
Microhylidae	2	1	1	1	1	1
Ranidae	11	—	6	4	7	3
Rhinophrynidae	1	—	1	—	—	—
Scaphiopodidae	1	—	—	—	1	1
Subtotals	44	10	25	24	24	12
Ambystomatidae	6	—	—	—	6	—
Plethodontidae	3	—	—	—	3	—
Subtotals	9	—	—	—	9	—
Caeciliidae	1	1	—	—	1	—
Subtotals	1	1	—	—	1	—
Totals	54	11	25	24	34	12
Crocodylidae	1	1	—	—	—	—
Subtotals	1	1	—	—	—	—
Cheloniidae	2	2	—	—	—	—
Dermochelyidae	1	1	—	—	—	—
Geoemydidae	2	2	1	1	—	—
Kinosternidae	2	1	1	1	2	2
Subtotals	7	6	2	2	2	2
Bipedidae	1	—	1	—	—	—
Anguidae	6	—	—	2	4	—
Corytophanidae	1	1	1	1	—	—
Dactyloidae	2	1	2	2	1	1
Eublepharidae	1	1	1	—	—	—
Gekkonidae	1	1	1	1	—	—
Helodermatidae	1	1	1	1	—	—
Iguanidae	3	2	3	2	—	—
Mabuyidae	1	1	1	—	—	—
Phrynosomatidae	20	6	9	13	12	4

Phyllodactylidae	5	3	3	2	1	—
Scincidae	6	2	1	3	3	—
Sphenomorphidae	1	1	1	1	—	—
Teiidae	8	4	7	6	1	1
Xantusiidae	1	1	1	—	—	—
Subtotals	58	25	33	34	22	6
Boidae	1	1	1	1	—	—
Colubridae	28	11	13	13	15	6
Dipsadidae	33	8	10	19	9	—
Elapidae	4	1	2	1	1	—
Leptotyphlopidae	4	—	4	1	—	—
Loxocemidae	1	—	1	1	—	—
Natricidae	11	2	1	2	7	3
Typhlopidae	1	—	1	1	1	—
Viperidae	10	3	3	3	6	—
Xenodontidae	2	2	2	1	—	—
Subtotals	95	28	38	43	39	9
Totals	161	60	73	79	63	17
Sum Totals	215	71	98	103	97	29

Anurans are more broadly represented in the Balsas-Tepalcatepec Depression, where 25 species classified in all but one of the nine families occurring in the state are found. These anurans are represented most narrowly on the Coastal



Plectrohyla bistincta. The Mexican fringe-limbed treefrog is distributed from Durango and Veracruz southward to México and Oaxaca. Its EVS has been assessed as 9, placing at the upper end of the low vulnerability category, this species is considered as Least Concern by IUCN, and as a Special Protection species by SEMARNAT. This individual came from San José de las Torres, near Morelia, in Michoacán.

Photo by Javier Alvarado-Díaz.

Plain, where only 10 species assigned to four families occur. One or more species in the families Bufonidae, Hylidae, and Microhylidae are distributed in each of the five provinces (Table 5). As expected, the family Hylidae is best represented in each of the provinces except for the Transverse Volcanic Axis, where more ranids (sev-

en species) than hylids (five) occur. All nine species of salamanders are limited in occurrence to the Transverse Volcanic Axis and the single caecilian to the Transverse Volcanic Axis and the Coastal Plain (Table 5).

Lizards are best represented in the Sierra Madre del Sur, with 34 species, but the Balsas-Tepalcatepec Depression falls only one behind, with 33 (Table 5). Both of these figures comprise more than one-half of the 58 species of lizards known from the state. Fewer than one-half of this number occurs on the Coastal Plain (25) and the Transverse Volcanic Axis (22). Only a few species (six) occur on the Central Plateau. In the families Dactyloidae, Phrynosomatidae, and Teiidae, one or more species is distributed in each of the five provinces (Table 5). Due to the size of the Phrynosomatidae in Michoacán (20 species), this family is the best represented in each of the provinces. Several lizard families are represented by a single species in each of the provinces, but only one with a single species (the Bipedidae) is limited to a single province (Table 5).

The largest number of snake species is known from the Sierra Madre del Sur, with 43 species. Fewer numbers are found in the Transverse Volcanic Axis (39), Balsas-Tepalcatepec Depression (38), Coastal Plain (28), and the Central Plateau (nine). One or more representatives of only two snake families, the Colubridae and Natricidae, are found in each of the five provinces (Table 5). Interestingly, although the Colubridae in Michoacán is represented by five fewer species than the Dipsadidae, it is the best-represented family in all of the provinces except for the Sierra Madre del Sur, in which the Dip-



Ambystoma velasci. The plateau tiger salamander is found along the Transverse Volcanic Axis in Michoacán and elsewhere, thence northward into both the Sierra Madre Occidental to northwestern Chihuahua and the Sierra Madre Oriental to southern Nuevo León. Its EVS has been assigned a value of 10, placing it at the lower end of the medium vulnerability category, its status has been judged as Least Concern by IUCN, and it is considered a Special Protection species by SEMARNAT. This individual came from Los Azufres, in the Transverse Volcanic Axis. *Photo by Javier Alvarado-Díaz.*

sadidae is the best represented. Only three snake families are represented by a single species (including the Typhlopidae, containing the non-native blindsnake *Ramphotyphlops braminus*), but in all three cases they occur in two or three provinces (Table 5).

Relatively few species of turtles have been recorded in Michoacán, and given that three of the seven are sea turtles, most of them (six) are known from the Coastal Plain (obviously, sea turtles come on land for egg deposition). Only two species of the families Geoemydidae and/or Kinosternidae are found in the remaining four provinces (Table 5). The single crocodylian species is found only in the Coastal Plain (Table 5).

We constructed a Coefficient of Biogeographic Resemblance (CBR) matrix to examine the herpetofaunal relationships among the five physiographic provinces (Table 6). The data in this table demonstrate that the greatest degree of resemblance (74 species shared, CBR value of 0.74) occurs between the Balsas-Tepalcatepec Depression and the Sierra Madre del Sur (Table 6). Whereas this fact might be considered counterintuitive, given the elevational distinction between the two areas, these two provinces broadly contact one another along

the northern and eastern face of the mountain mass (Fig. 1). A greater degree of resemblance might be expected between the Balsas-Tepalcatepec Depression and the Coastal Plain, inasmuch as these are relatively low-elevation areas, but they only contact one another where the Río Balsas flows onto the coastal plain prior to entering the Pacific Ocean. As a consequence, these two provinces share only 44 species and their CBR value is 0.52 (Table 6). Nonetheless, these values are the highest that the Coastal Plain shares with any of the other four provinces, with the exception of the Sierra Madre del Sur (44 species and 0.51). For a similar reason, it might be expected that the Balsas-Tepalcatepec Depression would share a relatively large number of species with the Transverse Volcanic Axis to the north, but this is not the case. Only 21 species are shared and the CBR value is only 0.22 (Table 6).

One might also presume that the Transverse Volcanic Axis and the Sierra Madre del Sur would share a sizable number of montane-distributed species, but the two provinces only share 29 species and their CBR value is 0.29. The Central Plateau is adjacent to the Transverse Volcanic Axis and the data in Table 6 demonstrate that

Table 6. CBR matrix of herpetofaunal relationships for the five physiographic provinces in Michoacán. N = species in each province; N = species in common between two provinces; N = Coefficients of Biogeographic Resemblance. The formula for this algorithm is $CBR = 2C/N1 + N2$, where C is the number of species in common to both provinces, N1 is the number of species in the first province, and N2 is the number of species in the second province.

	COP	BTD	SMS	TVA	CEP
COP	71	44	44	9	4
BTD	0.52	98	74	21	11
SMS	0.51	0.74	103	29	9
TVA	0.11	0.22	0.29	97	26
CEP	0.08	0.17	0.14	0.41	29

26 of the 29 species found in the Central Plateau also are recorded from the Transverse Volcanic Axis, but because of the disparity in the size of their respective herpetofaunas their CBR value is only 0.41. Nonetheless, this is the Central Plateau’s greatest degree of resemblance with any of the other four provinces.

As opposed to species shared between or among physiographic provinces, the distribution of some species is confined to a single province (Table 4), although sometimes these are more broadly distributed outside the state. In the Coastal Plain, the following 22 species are involved:

- Trachycephalus typhonius*
- Hypopachus ustus*
- Crocodylus acutus*
- Phyllodactylus davisii*
- Phyllodactylus homolepidurus*
- Plestiodon parvulus*
- Geagras redimitus*
- Symphimus leucostomus*
- Coniophanes michoacanensis*
- Coniophanes piceivittis*
- Enulius oligostichus*
- Leptodeira nigrofasciata*
- Leptodeira uribei*
- Pelamis platura*
- Thamnophis proximus*
- Thamnophis validus*
- Porthidium hespere*
- Plestiodon parvulus*
- Chelonia mydas*
- Lepidochelys olivacea*
- Dermochelys coriacea*
- Rhinoclemmys pulcherrima*

In the Balsas-Tepalcatepec Depression, the following 16 species are confined to this province:

- Eleutherodactylus maurus*
- Lithobates berlandieri*
- Lithobates magnaocularis*
- Rhinophrynus dorsalis*

- Bipes canaliculatus*
- Ctenosaura clarki*
- Phyllodactylus paucituberculatus*
- Aspidoscelis sacki*
- Imantodes gemmistratus*
- Leptodeira septentrionalis*
- Micrurus laticollaris*
- Rena bressoni*
- Rena humilis*
- Rena maxima*
- Thamnophis postremus*
- Crotalus culminatus*

The following 14 species are limited to the Sierra Madre del Sur, within the state:

- Eleutherodactylus modestus*
- Eleutherodactylus rufescens*
- Barisia jonesi*
- Elgaria kingii*
- Sceloporus bulleri*
- Sceloporus insignis*
- Coniophanes sarae*
- Dipsas gaigeae*
- Geophis incomptus*
- Geophis nigrocinctus*
- Geophis pyburni*
- Geophis sieboldi*
- Tropidodipsas annulifera*
- Tropidodipsas fasciata*

The herpetofauna of the Transverse Volcanic Axis in Michoacán contains the following 47 single-province species (*Lithobates catesbeianus*, a non-native species, is not listed):

- Craugastor hobartsmithi*
- Craugastor occidentalis*
- Eleutherodactylus angustidigitorum*
- Hyla plicata*
- Lithobates dunni*
- Lithobates spectabilis*
- Ambystoma amblycephalum*
- Ambystoma andersoni*

Ambystoma dumerilii
Ambystoma ordinarium
Ambystoma rivulare
Ambystoma velasci
Pseudoeurycea bellii
Pseudoeurycea leprosa
Pseudoeurycea longicauda
Abronia deppii
Barisia imbricata
Barisia rudicollis
Gerrhonotus liocephalus
Phrynosoma orbiculare
Sceloporus aeneus
Sceloporus grammicus
Plestiodon copei
Plestiodon dugesii
Conopsis biserialis
Conopsis nasus
Gyalopion canum
Lampropeltis ruthveni
Lampropeltis triangulum
Tantilla bocourti
Tantilla cascadae
Diadophis punctatus
Geophis bicolor

Geophis dugesii
Geophis maculiferus
Geophis tarascae
Rhadinaea laureata
Rhadinaea taeniata
Micrurus tener
Thamnophis melanogaster
Thamnophis pulchrilatus
Thamnophis scalaris
Crotalus aquilus
Crotalus molossus
Crotalus polystictus
Crotalus tancitarensis
Crotalus triseriatus

Finally, the Central Plateau herpetofauna includes only one species limited to this province, as follows:

Adelophis copei

In total, of the 212 native species, 100 (47.2%) are confined to a single physiographic province within the state. Organizing these single-province species by their distributional status (Table 7) indicates the following (listed in order of state endemics, country endemics, and non-endemic species): Coastal plain (22 total species) = 1 (4.5%), 10 (45.5%), 11 (50.0%); Balsas-Tepalcate-



Pseudoeurycea bellii. Bell's false brook salamander occurs from southern Tamaulipas and southern Nayarit southward to Tlaxcala and Guerrero, Mexico, with a disjunct population found in east-central Sonora and adjacent Chihuahua. Its EVS has been gauged as 12, placing it in the upper portion of the medium vulnerability category, its status has been judged as Vulnerable by IUCN, and it is regarded as Threatened by SEMARNAT. This individual was found and photographed on Cerro Tancítaro, Michoacán.
 Photo by Javier Alvarado-Díaz.

pec Depression (16 species) = 3 (18.8%), 7 (43.8%), 6 (37.4%); Sierra Madre del Sur (14 species) = 5 (35.7%), 8 (57.2%), 1 (7.1%); Transverse Volcanic Axis = 8 (17.0%), 32 (68.1%), 7 (14.9%); Central Plateau = 0 (0.0%), 1 (100%), 0 (0.0%). Most of these single-province species are country-level endemics (58 [58.0%]); and the remaining are non-endemics (25 [25.0%]) or state-level endemics (17 [17.0%]).

Conservation Status

We employed three systems in creating a comprehensive view of the conservation status of the amphibians and reptiles of Michoacán (see Materials and Methods), of which one was developed for use in Mexico (the SEMARNAT

system), another developed for use in Central America (the EVS system, Wilson and Johnson 2010) and later applied to Mexico (Wilson et al. 2013a,b), and a third developed for use on a global basis (the IUCN system). We discuss the application of these systems to the herpetofauna of Michoacán below.

Table 7. Distributional and conservation status measures for members of the herpetofauna of Michoacán, Mexico. Distributional Status: SE = endemic to state of Michoacán; CE = endemic to country of Mexico; NE = not endemic to state or country; NN = non-native. Environmental Vulnerability Score (taken from Wilson et al. 2013a,b): low vulnerability species (EVS of 3–9); medium vulnerability species (EVS of 10–13); high vulnerability species (EVS of 14–20). IUCN Categorization: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated. SEMARNAT Status: A = Threatened; P = Endangered; Pr = Special Protection; NS = No Status. See text for explanations of the EVS, IUCN, and SEMARNAT rating systems.

Taxa	Distributional Status	Environmental Vulnerability Score	IUCN Categorization	SEMARNAT Status
Amphibia (54 species)				
Anura (44 species)				
Bufonidae (6 species)				
<i>Anaxyrus compactilis</i>	CE	14	LC	NS
<i>Incilius marmoreus</i>	CE	11	LC	NS
<i>Incilius occidentalis</i>	CE	11	LC	NS
<i>Incilius perplexus</i>	CE	11	EN	NS
<i>Incilius pisinnus</i>	SE	15	DD	NS
<i>Rhinella marina</i>	NE	3	LC	NS
Craugastoridae (5 species)				
<i>Craugastor augusti</i>	NE	8	LC	NS
<i>Craugastor hobartsmithi</i>	CE	15	EN	NS
<i>Craugastor occidentalis</i>	CE	13	DD	NS
<i>Craugastor pygmaeus</i>	NE	9	VU	NS
<i>Craugastor vocalis</i>	CE	13	LC	NS
Eleutherodactylidae (5 species)				
<i>Eleutherodactylus angustidigitorum</i>	SE	17	VU	Pr
<i>Eleutherodactylus maurus</i>	CE	17	DD	Pr
<i>Eleutherodactylus modestus</i>	CE	16	VU	Pr
<i>Eleutherodactylus nitidus</i>	CE	12	LC	NS
<i>Eleutherodactylus rufescens</i>	SE	17	CR	Pr
Hylidae (11 species)				
<i>Agalychnis dacnicolor</i>	CE	13	LC	NS
<i>Diaglena spatulata</i>	CE	13	LC	NS

<i>Exerodonta smaragdina</i>	CE	12	LC	Pr
<i>Hyla arenicolor</i>	NE	7	LC	NS
<i>Hyla eximia</i>	NE	10	LC	NS
<i>Hyla plicata</i>	CE	11	LC	A
<i>Plectrohyla bistincta</i>	CE	9	LC	Pr
<i>Smilisca baudinii</i>	NE	3	LC	NS
<i>Smilisca fodiens</i>	NE	8	LC	NS
<i>Tlalocohyla smithii</i>	CE	11	LC	NS
<i>Trachycephalus typhonius</i>	NE	4	LC	NS
Leptodactylidae (2 species)				
<i>Leptodactylus fragilis</i>	NE	5	LC	NS
<i>Leptodactylus melanonotus</i>	NE	6	LC	NS
Microhylidae (2 species)				
<i>Hypopachus ustus</i>	NE	7	LC	Pr
<i>Hypopachus variolosus</i>	NE	4	LC	NS
Ranidae (11 species)				
<i>Lithobates berlandieri</i>	NE	7	LC	Pr
<i>Lithobates catesbeianus</i>	NN	—	—	—
<i>Lithobates dunni</i>	SE	14	EN	Pr
<i>Lithobates forreri</i>	NE	3	LC	Pr
<i>Lithobates magnaocularis</i>	CE	12	LC	NS
<i>Lithobates megapoda</i>	CE	14	VU	Pr
<i>Lithobates montezumae</i>	CE	13	LC	Pr
<i>Lithobates neovolcanicus</i>	CE	13	NT	A
<i>Lithobates pustulosus</i>	CE	9	LC	Pr
<i>Lithobates spectabilis</i>	CE	12	LC	NS
<i>Lithobates zweifeli</i>	CE	11	LC	NS
Rhinophrynidae (1 species)				
<i>Rhinophrynus dorsalis</i>	NE	8	LC	Pr
Scaphiopodidae (1 species)				
<i>Spea multiplicata</i>	NE	6	LC	NS
Caudata (9 species)				
Ambystomatidae (6 species)				
<i>Ambystoma amblycephalum</i>	SE	13	CR	Pr
<i>Ambystoma andersoni</i>	SE	15	CR	Pr
<i>Ambystoma dumerilii</i>	SE	15	CR	Pr
<i>Ambystoma ordinarium</i>	CE	13	EN	Pr
<i>Ambystoma rivulare</i>	CE	13	DD	A
<i>Ambystoma velasci</i>	CE	10	LC	Pr
Plethodontidae (3 species)				
<i>Pseudoeurycea bellii</i>	CE	12	VU	A
<i>Pseudoeurycea leprosa</i>	CE	16	VU	A
<i>Pseudoeurycea longicauda</i>	CE	17	EN	Pr
Gymnophiona (1 species)				
Caeciliidae (1 species)				
<i>Dermophis oaxacae</i>	CE	12	DD	Pr
Reptilia (161 species)				

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Crocodylia (1 species)				
Crocodylidae (1 species)				
<i>Crocodylus acutus</i>	NE	14	VU	Pr
Squamata (153 species)				
Bipedidae (1 species)				
<i>Bipes canaliculatus</i>	CE	12	LC	Pr
Anguidae (6 species)				
<i>Abronia deppii</i>	CE	16	EN	A
<i>Barisia imbricata</i>	CE	14	LC	Pr
<i>Barisia jonesi</i>	SE	16	NE	NS
<i>Barisia rudicollis</i>	CE	15	EN	P
<i>Elgaria kingii</i>	NE	10	LC	Pr
<i>Gerrhonotus liocephalus</i>	NE	6	LC	Pr
Corytophanidae (1 species)				
<i>Basiliscus vittatus</i>	NE	7	NE	NS
Dactyloidae (2 species)				
<i>Anolis dunni</i>	CE	16	LC	A
<i>Anolis nebulosus</i>	CE	13	LC	NS
Eublepharidae (1 species)				
<i>Coleonyx elegans</i>	NE	9	NE	A
Gekkonidae (1 species)				
<i>Hemidactylus frenatus</i>	NN	—	—	—
Helodermatidae (1 species)				
<i>Heloderma horridum</i>	NE	11	LC	A
Iguanidae (3 species)				
<i>Ctenosaura clarki</i>	CE	15	VU	A
<i>Ctenosaura pectinata</i>	CE	15	NE	A
<i>Iguana iguana</i>	NE	12	NE	Pr
Mabuyidae (1 species)				
<i>Marisora brachypoda</i>	NE	6	NE	NS
Phrynosomatidae (20 species)				
<i>Phrynosoma asio</i>	NE	11	NE	Pr
<i>Phrynosoma orbiculare</i>	CE	12	LC	A
<i>Sceloporus aeneus</i>	CE	13	LC	NS
<i>Sceloporus asper</i>	CE	14	LC	Pr
<i>Sceloporus bulleri</i>	CE	15	LC	NS
<i>Sceloporus dugesii</i>	CE	13	LC	NS
<i>Sceloporus gadoviae</i>	CE	11	LC	NS
<i>Sceloporus grammicus</i>	NE	9	LC	Pr
<i>Sceloporus heterolepis</i>	CE	14	LC	NS
<i>Sceloporus horridus</i>	CE	11	LC	NS
<i>Sceloporus insignis</i>	CE	16	LC	Pr
<i>Sceloporus melanorhinus</i>	NE	9	LC	NS
<i>Sceloporus pyrocephalus</i>	CE	12	LC	NS
<i>Sceloporus scalaris</i>	NE	12	LC	NS
<i>Sceloporus siniferus</i>	NE	11	LC	NS
<i>Sceloporus spinosus</i>	CE	12	LC	NS

<i>Sceloporus torquatus</i>	CE	11	LC	NS
<i>Sceloporus utiformis</i>	CE	15	LC	NS
<i>Urosaurus bicarinatus</i>	CE	12	LC	NS
<i>Urosaurus gadovi</i>	CE	12	LC	NS
Phyllodactylidae (5 species)				
<i>Phyllodactylus davisii</i>	CE	16	LC	A
<i>Phyllodactylus duellmani</i>	SE	16	LC	Pr
<i>Phyllodactylus homolepidurus</i>	CE	15	LC	Pr
<i>Phyllodactylus lanei</i>	CE	15	LC	NS
<i>Phyllodactylus paucituberculatus</i>	SE	16	DD	A
Scincidae (6 species)				
<i>Mesoscincus altamirani</i>	CE	14	DD	Pr
<i>Plestiodon colimensis</i>	CE	14	DD	Pr
<i>Plestiodon copei</i>	CE	14	LC	Pr
<i>Plestiodon dugesii</i>	CE	16	VU	Pr
<i>Plestiodon indubitus</i>	CE	15	LC	NS
<i>Plestiodon parvulus</i>	CE	15	DD	NS
Sphenomorphidae (1 species)				
<i>Sphenomorphus assatus</i>	NE	7	NE	NS
Teiidae (8 species)				
<i>Aspiloscelis calidipes</i>	SE	14	LC	Pr
<i>Aspiloscelis communis</i>	CE	14	LC	Pr
<i>Aspiloscelis costata</i>	CE	11	LC	Pr
<i>Aspiloscelis deppei</i>	NE	8	LC	NS
<i>Aspiloscelis gularis</i>	NE	9	LC	NS
<i>Aspiloscelis lineatissima</i>	CE	14	LC	Pr
<i>Aspiloscelis sacki</i>	CE	14	LC	NS
<i>Holcosus undulatus</i>	NE	7	NE	NS
Xantusiidae (1 species)				
<i>Lepidophyma tarascae</i>	CE	14	DD	A
Boidae (1 species)				
<i>Boa constrictor</i>	NE	10	NE	A
Colubridae (28 species)				
<i>Conopsis biserialis</i>	CE	13	LC	A
<i>Conopsis lineata</i>	CE	13	LC	NS
<i>Conopsis nasus</i>	CE	11	LC	NS
<i>Drymarchon melanurus</i>	NE	6	LC	NS
<i>Drymobius margaritiferus</i>	NE	6	NE	NS
<i>Geagras redimitus</i>	CE	14	DD	Pr
<i>Gyalopion canum</i>	NE	9	LC	NS
<i>Lampropeltis ruthveni</i>	CE	16	NT	A
<i>Lampropeltis triangulum</i>	NE	7	NE	A
<i>Leptophis diplotropis</i>	CE	14	LC	A
<i>Masticophis flagellum</i>	NE	8	LC	A
<i>Masticophis mentovarius</i>	NE	6	NE	A
<i>Masticophis taeniatus</i>	NE	10	LC	NS
<i>Mastigodryas melanolomus</i>	NE	6	LC	NS

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<i>Oxybelis aeneus</i>	NE	5	NE	NS
<i>Pituophis deppei</i>	CE	14	LC	A
<i>Pituophis lineaticollis</i>	NE	8	LC	NS
<i>Pseudoficimia frontalis</i>	CE	13	LC	Pr
<i>Salvadora bairdi</i>	CE	15	LC	Pr
<i>Salvadora mexicana</i>	CE	15	LC	Pr
<i>Senticolis triaspis</i>	NE	6	NE	NS
<i>Sonora michoacanensis</i>	CE	14	LC	NS
<i>Symphimus leucostomus</i>	CE	14	LC	Pr
<i>Tantilla bocourti</i>	CE	9	LC	NS
<i>Tantilla calamarina</i>	CE	12	LC	Pr
<i>Tantilla cascadae</i>	SE	16	DD	A
<i>Trimorphodon biscutatus</i>	NE	7	NE	NS
<i>Trimorphodon tau</i>	CE	13	LC	NS
Dipsadidae (33 species)				
<i>Coniophanes fissidens</i>	NE	7	NE	NS
<i>Coniophanes lateritius</i>	CE	13	DD	NS
<i>Coniophanes michoacanensis</i>	SE	17	NE	NS
<i>Coniophanes piceivittis</i>	NE	7	LC	NS
<i>Coniophanes sarae</i>	SE	16	DD	NS
<i>Diadophis punctatus</i>	NE	4	LC	NS
<i>Dipsas gaigeae</i>	CE	17	LC	Pr
<i>Enulius flavitorques</i>	NE	5	NE	NS
<i>Enulius oligostichus</i>	CE	15	DD	Pr
<i>Geophis bicolor</i>	CE	15	DD	Pr
<i>Geophis dugesii</i>	CE	13	LC	NS
<i>Geophis incomptus</i>	SE	16	DD	Pr
<i>Geophis maculiferus</i>	SE	16	DD	Pr
<i>Geophis nigrocinctus</i>	CE	15	DD	Pr
<i>Geophis petersii</i>	CE	15	DD	Pr
<i>Geophis pyburni</i>	SE	16	DD	Pr
<i>Geophis sieboldi</i>	CE	13	DD	Pr
<i>Geophis tarascae</i>	CE	15	DD	Pr
<i>Hypsiglena torquata</i>	NE	8	LC	Pr
<i>Imantodes gemmistratus</i>	NE	6	NE	Pr
<i>Leptodeira maculata</i>	CE	7	LC	Pr
<i>Leptodeira nigrofasciata</i>	NE	8	LC	NS
<i>Leptodeira septentrionalis</i>	NE	8	NE	NS
<i>Leptodeira splendida</i>	CE	14	LC	NS
<i>Leptodeira uribei</i>	CE	17	LC	Pr
<i>Pseudoleptodeira latifasciata</i>	CE	14	LC	Pr
<i>Rhadinaea hesperia</i>	CE	10	LC	Pr
<i>Rhadinaea laureata</i>	CE	12	LC	NS
<i>Rhadinaea taeniata</i>	CE	13	LC	NS
<i>Sibon nebulatus</i>	NE	5	NE	NS
<i>Tropidodipsas annulifera</i>	CE	13	LC	Pr
<i>Tropidodipsas fasciata</i>	CE	13	NE	NS

<i>Tropidodipsas philippii</i>	CE	14	LC	Pr
Elapidae (4 species)				
<i>Micrurus distans</i>	CE	14	LC	Pr
<i>Micrurus laticollaris</i>	CE	14	LC	Pr
<i>Micrurus tener</i>	NE	11	LC	NS
<i>Pelamis platura</i>	NE	—	LC	NS
Leptotyphlopidae (4 species)				
<i>Epictia goudotii</i>	NE	3	NE	NS
<i>Rena bressoni</i>	SE	14	DD	Pr
<i>Rena humilis</i>	NE	8	LC	NS
<i>Rena maxima</i>	CE	11	LC	NS
Loxocemidae (1 species)				
<i>Loxocemus bicolor</i>	NE	10	NE	Pr
Natricidae (11 species)				
<i>Adelophis copei</i>	CE	15	VU	Pr
<i>Storeria storerioides</i>	CE	11	LC	NS
<i>Thamnophis cyrtopsis</i>	NE	7	LC	A
<i>Thamnophis eques</i>	NE	8	LC	A
<i>Thamnophis melanogaster</i>	CE	15	EN	A
<i>Thamnophis postremus</i>	SE	15	LC	NS
<i>Thamnophis proximus</i>	NE	7	NE	NS
<i>Thamnophis pulchrilatus</i>	CE	15	LC	NS
<i>Thamnophis scalaris</i>	CE	14	LC	A
<i>Thamnophis scaliger</i>	CE	15	VU	A
<i>Thamnophis validus</i>	CE	12	LC	NS
Typhlopidae (1 species)				
<i>Ramphotyphlops braminus</i>	NN	—	—	—
Viperidae (10 species)				
<i>Agkistrodon bilineatus</i>	NE	11	NT	Pr
<i>Crotalus aquilus</i>	CE	16	LC	Pr
<i>Crotalus basiliscus</i>	CE	16	LC	Pr
<i>Crotalus culminatus</i>	CE	15	NE	NS
<i>Crotalus molossus</i>	NE	8	LC	Pr
<i>Crotalus polystictus</i>	CE	16	LC	Pr
<i>Crotalus pusillus</i>	CE	18	EN	A
<i>Crotalus tancitarensis</i>	SE	19	DD	NS
<i>Crotalus triseriatus</i>	CE	16	LC	NS
<i>Porthidium hespere</i>	CE	18	DD	Pr
Xenodontidae (2 species)				
<i>Conophis vittatus</i>	CE	11	LC	NS
<i>Manolepis putnami</i>	CE	13	LC	NS
Testudines (7 species)				
Cheloniidae (2 species)				
<i>Chelonia mydas</i>	NE	—	EN	P
<i>Lepidochelys olivacea</i>	NE	—	VU	P
Dermochelyidae (1 species)				
<i>Dermochelys coriacea</i>	NE	—	CR	P

Geoemydidae (2 species)				
<i>Rhinoclemmys pulcherrima</i>	NE	8	NE	A
<i>Rhinoclemmys rubida</i>	CE	14	NT	Pr
Kinosternidae (2 species)				
<i>Kinosternon hirtipes</i>	NE	10	LC	Pr
<i>Kinosternon integrum</i>	CE	11	LC	Pr



Pseudoeurycea leprosa. The leprous false brook salamander occurs in Veracruz, Puebla, Distrito Federal, México, Morelos, Guerrero, and Oaxaca. Its EVS has been judged as 16, placing it in the middle of the high vulnerability category, IUCN has assessed this species as Vulnerable, and it is considered as Threatened by SEMARNAT. This individual was encountered on Cerro Cacique, near Zitacuaro, in Michoacán. *Photo by Oscar Medina-Aguilar.*



Abronia deppii. Deppe's arboreal alligator lizard is found in the mountains of the Transverse Volcanic Axis in Michoacán, México, and Jalisco. Its EVS has been judged as 16, placing it in the middle of the high vulnerability category, IUCN considers this species as Endangered, and it has been provided a Threatened status by SEMARNAT. This individual came from San José de las Torres, near Morelia, in Michoacán. *Photo by Javier Alvarado-Díaz.*



Barisia imbricata. In Michoacán, the imbricate alligator lizard occurs in the Transverse Volcanic Axis. The systematics of this species, however, is currently in flux, and based on indications in recent molecular work this taxon likely will be divided into a number of species. Its EVS has been estimated as 14, placing it at the lower end of the high vulnerability category, this species has been judged as Least Concern by IUCN, and given a Special Protected status by SEMARNAT. This individual is from Tacámbaro, in the Transverse Volcanic Axis of Michoacán. Photo by Oscar Medina-Aguilar.

1. The SEMARNAT system

The application of the SEMARNAT system appears in NOM-059-SEMARNAT-2010 (available at www.semarnat.gob.mx), and uses three categories: Endangered (P), Threatened (A), and Special Protection (Pr). In addition to these categories, we considered the species left untreated in the SEMARNAT system as having “No status.” We listed the SEMARNAT categorizations in Table 7 and summarized the results of the partitioning of the 212 native species in Table 8.

Perusal of the tabular data reveals one important conclusion—almost one-half of the species in Michoacán (98 [46.2%]) are not considered in the SEMARNAT system (Table 8). The missing species include 27 anurans, 27 lizards, and 44 snakes, and include the following: all six of the bufonids, of which five are Mexican endemic species (one is endemic to Michoacán); all five of the craugas-torids, of which three are Mexican endemics; eight of 11 hylids, of which three are Mexican endemics; one of two dactyloids, which one is a Mexican endemic; 15 of

20 phrynosomatids, of which 12 are Mexican endemics; one-half of the 28 colubrids, of which five are Mexican endemics; 15 of 33 dipsadids, of which eight are Mexican endemics (two also are state endemics); four of 11 natri-cids, of which four are Mexican endemics (one also is a state endemic); and two of 10 viperids, of which two are Mexican endemics (one also is a state endemic).

Of the 212 total species, only four (1.9%) are judged as Endangered (three are sea turtles from the coastal waters of the state and one is the anguid *Abronia deppii*). Thirty-one species (14.6%) are considered as Threatened and 79 (37.1%) as needing Special Protection (Table 8).

In the end, any system purporting to at least identify species in need of conservation attention is better than no system at all. The SEMARNAT system, however, is seriously deficient because a high percentage of species are not provided with a conservation status, and a significant portion of these taxa are state or country level endemics. We address our concerns in the Conclusions and Recommendations section.

Table 8. SEMARNAT categorizations for amphibians and reptiles in Michoacán arranged by families. Non-native species are excluded.

Families	Number of Species	SEMARNAT Categorizations			
		Endangered (P)	Threatened (A)	Special Protection (Pr)	No Status
Bufonidae	6	—	—	—	6
Craugastoridae	5	—	—	—	5
Eleutherodactylidae	5	—	—	4	1
Hylidae	11	—	1	2	8
Leptodactylidae	2	—	—	—	2
Microhylidae	2	—	—	1	1
Ranidae	10	—	1	6	3
Rhinophrynidae	1	—	—	1	—
Scaphiopodidae	1	—	—	—	1
Subtotals	43	—	2	14	27
Ambystomatidae	6	—	1	5	—
Plethodontidae	3	—	2	1	—
Subtotals	9	—	3	6	—
Caeciliidae	1	—	—	1	—
Subtotals	1	—	—	1	—
Totals	53	—	5	21	27
Crocodylidae	1	—	—	1	—
Subtotals	1	—	—	1	—
Cheloniidae	2	2	—	—	—
Dermochelyidae	1	1	—	—	—
Geoemydidae	2	—	1	1	—
Kinosternidae	2	—	—	2	—
Subtotals	7	3	1	3	—
Bipedidae	1	—	—	1	—
Anguidae	6	1	1	3	1
Corytophanidae	1	—	—	—	1
Dactyloidae	2	—	1	—	1
Eublepharidae	1	—	1	—	—
Helodermatidae	1	—	1	—	—
Iguanidae	3	—	2	1	—
Mabuyidae	1	—	—	—	1
Phrynosomatidae	20	—	1	4	15
Phyllodactylidae	5	—	2	2	1
Scincidae	6	—	—	4	2
Sphenomorphidae	1	—	—	—	1
Teiidae	8	—	—	4	4
Xantusiidae	1	—	1	—	—
Subtotals	57	1	10	19	27
Boidae	1	—	1	—	—
Colubridae	28	—	8	6	14
Dipsadidae	33	—	—	18	15

Leptotyphlopidae	4	—	—	1	3
Loxocemidae	1	—	—	1	—
Natricidae	11	—	5	1	5
Viperidae	10	—	1	6	3
Xenodontidae	2	—	—	—	2
Subtotals	94	—	15	35	44
Totals	159	4	26	58	71
Sum Totals	212	4	31	79	98

2. The IUCN system



Coleonyx elegans. The elegant banded gecko is broadly distributed on both versants, from southern Nayarit and Veracruz in Mexico southward to Guatemala and Belize. In Michoacán, it inhabits the Coastal Plain and Balsas-Tepalcatepec Depression physiographic provinces. Its EVS has been indicated as 9, placing it at the upper end of the low vulnerability category, its IUCN status has not been assessed, and this gecko is regarded as Threatened by SEMARNAT. This individual came from Colola, on the coast of Michoacán. *Photo by Javier Alvarado-Díaz.*



Ctenosaura clarki. The Balsas armed lizard is endemic to the Balsas-Tepalcatepec Depression. Its EVS has been gauged as 15, placing it in the lower portion of the high vulnerability category, this species has been judged as Vulnerable by IUCN, and considered as Threatened by SEMARNAT. This individual is from Nuevo Centro, Reserva de la Biósfera Infiernillo-Zicuirán, near the Presa Infiernillo on the Río Balsas in southeastern Michoacán. *Photo by Javier Alvarado-Díaz.*

The IUCN system is the most widely used system for categorizing the conservation status of the world’s organisms, although it is skewed heavily toward chordate animals, as assessed by Stuart et al. (2010b). Of the 64,788 described chordate species, 27,882 (43.0%) had been assessed on the IUCN Red List by the year 2009; comparatively, only 7,615 of 1,359,365 species of other described animals had been assessed, a miniscule 0.56%. In fact, if all of the 1,424,153 animal species treated in Stuart et al. (2010b) are considered, only 2.5% have been assessed on the IUCN Red List. This extant situation is not so much of a criticism of the effectiveness of the IUCN system, but rather a criticism of the lack of attention given to conservation of the world’s organisms by humanity at large (Wilson 2002). As a case in point, Stuart et al. (2010b) reported that if a provisional target number of 106,979 animal species (only 7.5% of the total number of described species) were established in attempting to develop a broader taxonomic base of threatened animal species, the estimated cost to complete would be about \$36,000,000. Completion of a threatened species assess-

ment, however, is only the first step toward providing a given species adequate protection for perpetuity.

We listed the current IUCN Red List categorizations for the Michoacán herpetofauna in Table 7 and summarized the results in Table 9. The allocations of the 212 species assessed to the seven IUCN categories are as follows: Critically Endangered (CR) = 5 species (2.3%); Endangered (E) = 10 (4.7%); Vulnerable (VU) = 12 (5.6%); Near Threatened (NT) = 4 (1.9%); Least Concern (LC) = 127 (60.0%); Data Deficient (DD) = 26 (12.3%); and Not Evaluated (NE) = 28 (13.2%). These results are typical of those allocated for all Mexican amphibians and reptiles (see Wilson et al. 2013a,b). As a consequence, only 27 of the 213 species (12.7%) occupy the threatened categories (CR, EN, or VU). Six of every 10 species are judged at the lowest level of concern (LC). Finally, 54 species (25.5%) have been assessed either as DD or have not been assessed (NE).

Table 9. IUCN Red List categorizations for amphibian and reptile families in Michoacán. Non-native species are excluded.

Families	Number of Species	IUCN Red List categorizations						
		Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Bufonidae	6	—	1	—	—	4	1	—
Craugastoridae	5	—	1	1	—	2	1	—
Eleutherodactylidae	5	1	—	2	—	1	1	—
Hylidae	11	—	—	—	—	11	—	—
Leptodactylidae	2	—	—	—	—	2	—	—
Microhylidae	2	—	—	—	—	2	—	—
Ranidae	10	—	1	1	1	7	—	—
Rhinophrynidae	1	—	—	—	—	1	—	—
Scaphiopodidae	1	—	—	—	—	1	—	—
Subtotals	43	1	3	4	1	31	3	—
Ambystomatidae	6	3	1	—	—	1	1	—
Plethodontidae	3	—	1	2	—	—	—	—
Subtotals	9	3	2	2	—	1	1	—
Caeciliidae	1	—	—	—	—	—	1	—
Subtotals	1	—	—	—	—	—	1	—
Totals	53	4	5	6	1	32	5	—
Crocodylidae	1	—	—	1	—	—	—	—
Subtotals	1	—	—	1	—	—	—	—
Cheloniidae	2	—	1	1	—	—	—	—
Dermochelyidae	1	1	—	—	—	—	—	—
Geoemydidae	2	—	—	—	1	—	—	1
Kinosternidae	2	—	—	—	—	2	—	—
Subtotals	7	1	1	1	1	2	—	1
Bipedidae	1	—	—	—	—	1	—	—
Anguidae	6	—	2	—	—	3	—	1

Corytophanidae	1							1
Dactyloidae	2	—	—	—	—	2	—	—
Eublepharidae	1	—	—	—	—	—	—	1
Helodermatidae	1	—	—	—	—	1	—	—
Iguanidae	3	—	—	1	—	—	—	2
Mabuyidae	1	—	—	—	—	—	—	1
Phrynosomatidae	20	—	—	—	—	19	—	1
Phyllodactylidae	5	—	—	—	—	4	1	—
Scincidae	6	—	—	1	—	2	3	—
Sphenomorphidae	1	—	—	—	—	—	—	1
Teiidae	8	—	—	—	—	7	—	1
Xantusiidae	1	—	—	—	—	—	1	—
Subtotals	57	—	2	2	—	39	5	9
Boidae	1	—	—	—	—	—	—	1
Colubridae	28	—	—	—	1	19	2	6
Dipsadidae	33	—	—	—	—	15	11	7
Elapidae	4	—	—	—	—	4	—	—
Leptotyphlopidae	4	—	—	—	—	2	1	1
Loxocemidae	1	—	—	—	—	—	—	1
Natricidae	11	—	1	2	—	7	—	1
Viperidae	10	—	1	—	1	5	2	1
Xenodontidae	2	—	—	—	—	2	—	—
Subtotals	94	—	2	2	2	54	16	19
Totals	151	1	5	6	3	96	21	28
Sum Totals	212	5	10	12	4	127	26	28



Phyllodactylus duellmani. Duellman’s pigmy leaf-toed gecko is endemic to Michoacán, where it is found in the Balsas-Tepalcatepec Depression and the Sierra Madre del Sur. Its EVS has been assigned a value of 16, placing it in the middle of the high vulnerability category, this species has been judged as Least Concern by IUCN, and accorded a Special Protection status by SEMARNAT. This individual was photographed at Nuevo Centro, Reserva de la Biósfera Infiernillo-Zicuirán, near the Presa Infiernillo on the Río Balsas in southeastern Michoacán. *Photo by Oscar Medina-Aguilar.*



Leptodeira uribei. Uribe's cat-eyed snake is distributed along the coastal plain in Michoacán, and northward through the lowlands to Jalisco and southward to Oaxaca. Its EVS has been gauged as 17, placing it in the middle of the high vulnerability category, its IUCN status has been assessed as Least Concern, and it is considered a Special Protection species by SEMARNAT. This individual was found at San Mateo, near the Reserva de la Biosfera Chamela-Cuixmala on the coast of Jalisco. *Photo by Javier Alvarado-Díaz.*



Thamnophis postremus. The Michoacán gartersnake is a state endemic. Its EVS has been allocated as 15, placing it in the lower portion of the high vulnerability category, it has been judged as Least Concern by IUCN, and this species has not been provided a status by SEMARNAT. This individual came from San Lucas in the Balsas-Tepalcatepec Depression in Michoacán. *Photo by Javier Alvarado-Díaz.*

Based on the application of this system, only a small percentage of the species in the state would be scheduled to receive the greatest amount of attention. These 27 species include eight anurans, seven salamanders, one crocodylian, three turtles, four lizards, and four snakes. Whereas most of these species appear to merit a threatened status, inasmuch as 16 of the 27 species are country-level endemics and six are state-level endemics (22 species, 81.5% of the 27), the herpetofauna of Michoacán is characterized by a higher level of endemism than for the entire country of Mexico (140 of 212 species [66.0%] vs. 736 of 1,227 species [60.0%]). If endemism can be considered an important criterion for listing a species as threatened under the IUCN system (which it is not, as this system exists), then a substantial number of other candidates are available for choosing (Table 10), a significant issue that needs to be addressed.

A similar issue is the number of species judged as Data Deficient (Table 9). Of these 26 species, 17 are country and nine are state level endemics. Assignment of the DD status leaves these species in limbo, and requires additional fieldwork before applying for a change in a species' status. Other papers in this special Mexico issue have criticized the use of the DD category, with Wilson et al. (2013b) labeling these species as "threat species in disguise." The significance of such species can be ignored in the "rush to judgment" that sometimes accompanies assessments conducted using the IUCN system (NatureServe Press Release 2007).

Another problem with the use of the IUCN system is discussed in the lead-in paragraph to this section, i.e., that some species have not been evaluated

(the NE species). Given the average cost of producing an IUCN threat assessment for a single species (\$534.12, according to the figures in Stuart et al. 2010b), it takes a considerable investment to assign a species to a category other than NE. Nonetheless, one is left with relegating such species to a “wastebasket of neglect.” In the case of the Michoacán herpetofauna, 28 species fall into this category, including nine lizards and 19 snakes (Table 9). To be fair, the distributions of most of these species (21) extends outside of Mexico and thus were assessed in a Central American Workshop held in May of 2012 in Costa Rica (Rodríguez et al. 2013). At that workshop, most of these species were assigned an LC status.

Adding more species to the LC category is not necessarily a beneficial step, inasmuch as this category

was described as a “dumping ground” by Wilson et al. (2013b), who opined that “a more discerning look would demonstrate that many of these species should be partitioned into IUCN categories other than LC,” e.g., the threat categories and NT. Currently, 127 of the 212 native species of amphibians and reptiles (59.9%) are placed in the LC category (Table 9), which includes 31 anurans, one salamander, two turtles, 39 lizards, and 54 snakes. We question these assignments on the basis that 83 of these species are country-level endemics, and three (*Phyllodactylus duellmani*, *Aspidoscelis calidipes*, and *Thamnophis postremus*) also are state-level endemics (Table 7).

Table 10. Summary of the distributional status of amphibian and reptile families in Michoacán.

Families	Number of Species	Distributional Status			
		Non-endemic (NE)	Country Endemic (CE)	State Endemic (SE)	Non-native (NN)
Bufonidae	6	1	4	1	—
Craugastoridae	5	2	3	—	—
Eleutherodactylidae	5	—	3	2	—
Hylidae	11	5	6	—	—
Leptodactylidae	2	2	—	—	—
Microhylidae	2	2	—	—	—
Ranidae	11	2	7	1	1
Rhinophrynidae	1	1	—	—	—
Scaphiopodidae	1	1	—	—	—
Subtotals	44	16	23	4	1
Ambystomatidae	6	—	3	3	—
Plethodontidae	3	—	3	—	—
Subtotals	9	—	6	3	—
Caeciliidae	1	—	1	—	—
Subtotals	1	—	1	—	—
Totals	54	16	30	7	1
Crocodylidae	1	1	—	—	—
Subtotals	1	1	—	—	—
Cheloniidae	2	2	—	—	—
Dermochelyidae	1	1	—	—	—
Geoemydidae	2	1	1	—	—
Kinosternidae	2	1	1	—	—
Subtotals	7	5	2	—	—
Bipedidae	1	—	1	—	—
Anguidae	6	2	3	1	—
Corytophanidae	1	1	—	—	—
Dactyloidae	2	—	2	—	—

Gekkonidae	1	—	—	—	1
Helodermatidae	1	1	—	—	—
Iguanidae	3	1	2	—	—
Mabuyidae	1	1	—	—	—
Phrynosomatidae	20	5	15	—	—
Phyllodactylidae	5	—	3	2	—
Scincidae	6	—	6	—	—
Sphenomorphidae	1	1	—	—	—
Teiidae	8	3	4	1	—
Xantusiidae	1	—	1	—	—
Subtotals	58	16	37	4	1
Boidae	1	1	—	—	—
Colubridae	28	12	15	1	—
Dipsadidae	33	9	19	5	—
Elapidae	4	2	2	—	—
Leptotyphlopidae	4	2	1	1	—
Loxocemidae	1	1	—	—	—
Natricidae	11	3	7	1	—
Typhlopidae	1	—	—	—	1
Viperidae	10	2	7	1	—
Xenodontidae	2	—	2	—	—
Subtotals	95	32	53	9	1
Totals	161	54	92	13	2
Sum Totals	215	70	122	20	3

3. The EVS system



Rena bressoni. The Michoacán slender blindsnake is a state endemic, and its distribution is limited to the Balsas-Tepalcatepec Depression. Its EVS has been estimated as 14, placing it at the lower end of the high vulnerability category, it has been judged as Data Deficient by IUCN, and SEMARNAT considers it a Special Protection species. This individual was found in the municipality of Tacámbaro in Michoacán. *Photo by Oscar Medina-Aguilar.*



Crotalus basiliscus. The west coast Mexican rattlesnake is distributed from southern Sonora to northwestern Michoacán. In Michoacán, it is found in the Coastal Plain, Sierra Madre del Sur, and the Balsas-Tepalcatepec Depression physiographic provinces. Its EVS has been reported as 16, placing it in the middle of the high vulnerability category, it has been assessed as Least Concern by IUCN, and it is regarded as a Special Protection species by SEMARNAT. This individual is from San Mateo, on the coast of Jalisco. Photo by Oscar Medina-Aguilar.



Crotalus pusillus. The Tancitaran dusky rattlesnake is found in the Sierra de Coalcomán region of the Sierra Madre del Sur and the western portion of the Transverse Volcanic Axis. Its EVS has been estimated as 18, placing it in the upper portion of the high vulnerability category, it has been assessed as Endangered by IUCN, and it is considered as Threatened by SEMARNAT. This individual came from Cerro Tancítaro, the highest mountain in Michoacán, located in the west-central portion of the state. Photo by Javier Alvarado-Díaz.

The EVS (Environmental Vulnerability Score) system of conservation assessment first was applied to the herpetofauna of Honduras by Wilson and McCranie (2004). Since that time, this system has been applied to the herpetofaunas of Belize (Stafford et al. 2010), Guatemala (Acevedo et al. 2010), Nicaragua (Sunyer and Köhler 2010), Costa Rica (Sasa et al. 2010), and Panama (Jaramillo et al. 2010). In this special Mexico issue, the EVS measure also has been applied to the herpetofauna of Mexico (Wilson et al. 2013a,b).

In this paper, we utilized the scores computed by Wilson et al (2013a,b), which are indicated in Table 7 and summarized in Table 11 for the 208 species for which the scores are calculable. We arranged the resultant scores into three categories (low, medium, and high vulnerability), which were established by Wilson and McCranie (2004).

The EVS for members of the Michoacán herpetofauna range from 3 to 19 (Table 11). The lowest score of 3 was calculated for three anurans (the bufonid *Rhinella marina*, the hylid *Smilisca baudinii*, and the ranid *Lithobates forreri*) and one snake (the leptotyphlopoid *Epicrionia goudotii*). The highest value of 19 was assigned to the viperid *Crotalus tancitarensis*.

The summed scores for the entire herpetofauna vascillate over the range, but still generally rise from the lower scores of 3 through 5 to peak at 14 and decline thereafter (Table 11). Similar patterns are seen for amphibians and reptiles separately, although the species numbers for amphibians peak at an EVS of 13 instead of 14, as is the case for reptiles.

Table 11. Environmental Vulnerability Scores (EVS) for amphibian and reptile species in Michoacán, arranged by family. Shaded area to the left encompasses low vulnerability scores, and to the right high vulnerability scores.

Families	Number of Species	Environmental Vulnerability Scores																
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Bufo	6	1	—	—	—	—	—	—	—	3	—	—	1	1	—	—	—	—
Craugastor	5	—	—	—	—	—	1	1	—	—	—	2	—	1	—	—	—	—
Eleutherodactyl	5	—	—	—	—	—	—	—	—	—	1	—	—	—	1	3	—	—
Hyla	11	1	1	—	—	1	1	1	1	2	1	2	—	—	—	—	—	—
Leptodactyl	2	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Microhyla	2	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Rana	10	1	—	—	—	1	—	1	—	1	2	2	2	—	—	—	—	—
Rhinophryn	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Scaphiopod	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Subtotals	43	3	2	1	2	3	3	3	1	6	4	6	3	2	1	3	—	—
Subtotals %	—	7.0	4.6	2.3	4.6	7.0	7.0	7.0	2.3	14.0	9.3	14.0	7.0	4.6	2.3	7.0	—	—
Ambystomat	6	—	—	—	—	—	—	—	1	—	—	3	—	2	—	—	—	—
Plethodont	3	—	—	—	—	—	—	—	—	—	1	—	—	—	1	1	—	—
Subtotals	9	—	—	—	—	—	—	—	1	—	1	3	—	2	1	1	—	—
Subtotals %	—	—	—	—	—	—	—	—	11.1	—	11.1	33.3	—	22.2	11.1	11.1	—	—
Caecili	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Subtotals	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Subtotals %	—	—	—	—	—	—	—	—	—	—	100	—	—	—	—	—	—	—
Totals	53	3	2	1	2	3	3	3	2	6	6	9	3	4	2	4	—	—
Totals %	—	5.7	3.8	1.9	3.8	5.7	5.7	5.7	3.8	11.3	11.3	16.8	5.7	7.5	3.8	7.5	—	—
Crocodyl	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Subtotals		—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Subtotal %	—	—	—	—	—	—	—	—	—	—	—	—	100	—	—	—	—	—
Geoemyd	2	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—
Kinostern	2	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—
Subtotals	4	—	—	—	—	—	1	—	1	1	—	—	1	—	—	—	—	—
Subtotal %	—	—	—	—	—	—	25.0	—	25.0	25.0	—	—	25.0	—	—	—	—	—
Biped	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Angu	6	—	—	—	1	—	—	—	1	—	—	—	1	1	2	—	—	—
Corytophan	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Dactyl	2	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—
Eublephar	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Heloderma	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Iguan	3	—	—	—	—	—	—	—	—	—	1	—	—	2	—	—	—	—
Mabuy	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Phrynosoma	20	—	—	—	—	—	—	2	—	5	6	2	2	2	1	—	—	—
Phyllodactyl	5	—	—	—	—	—	—	—	—	—	—	—	—	2	3	—	—	—
Scinc	6	—	—	—	—	—	—	—	—	—	—	—	3	2	1	—	—	—
Sphenomor	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Tei	8	—	—	—	—	1	1	1	—	1	—	—	4	—	—	—	—	—
Xantusi	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Subtotals	57	—	—	—	2	3	1	4	1	7	8	3	11	9	8	—	—	—
Subtotal %	—	—	—	—	3.5	5.3	1.8	7.0	1.8	12.3	14.0	5.3	19.3	15.7	14.0	—	—	—
Boid	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Colubrid	28	—	—	1	5	2	2	2	1	1	1	4	5	2	2	—	—	—
Dipsad	33	—	1	2	1	3	3	—	1	—	1	6	3	5	4	3	—	—
Elap	3	—	—	—	—	—	—	—	—	1	—	—	2	—	—	—	—	—
Leptotyphlop	4	1	—	—	—	—	1	—	—	1	—	—	1	—	—	—	—	—
Loxocem	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Natric	11	—	—	—	—	2	1	—	—	1	1	—	1	5	—	—	—	—
Viper	10	—	—	—	—	—	1	—	—	1	—	—	—	1	4	—	2	1

Xenodontidae	2	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—
Subtotals	93	1	1	3	6	7	8	2	4	6	3	11	12	13	10	3	2	1
Subtotal %	—	1.1	1.1	3.2	6.4	7.5	8.6	2.2	4.3	6.4	3.2	11.8	12.9	14.0	10.8	3.2	2.2	1.1
Totals	155	1	1	3	8	10	10	6	6	14	11	14	25	22	18	3	2	1
Total %	—	0.6	0.6	1.9	5.2	6.5	6.5	3.9	3.9	9.0	7.1	9.0	16.1	14.2	11.6	1.9	1.3	0.6
Sum Totals	208	4	3	4	10	13	13	9	8	20	17	23	28	26	20	7	2	1
Sum Totals %	—	1.9	1.4	1.9	4.8	6.3	6.3	4.3	3.8	9.6	8.2	11.1	13.5	12.5	9.6	3.3	1.0	0.5

After organizing the EVS into low, medium, and high categories, a number of conclusions of conservation significance are apparent. The absolute and relative numbers for each of these categories, from low to high arranged

by major herpetofaunal group, are as follows: anurans = 17 (39.5%), 17 (39.5%), 9 (21.0%); salamanders = 0 (0.0%), 5 (55.6%), 4 (44.4%); caecilians = 0 (0.0%), 1 (100%), 0 (0.0%); crocodylians = 0 (0.0%), 0 (0.0%), 1 (100%); turtles = 1 (25.0%), 2 (50.0%), 1 (25.0%); lizards = 10 (17.6%), 19 (33.3%), 28 (49.1%); and snakes = 28 (30.1%), 25 (26.9%), 40 (43.0%). The highest absolute and relative numbers for each of the amphibian groups fall into the medium range, evident when these numbers are added, as follows: 17 (32.1); 23 (43.4); and 13 (24.5). For the reptile groups, the pattern is different in that the largest absolute and relative numbers for all groups, except for turtles, fall into the high range. Summing these numbers illustrates the general trend for reptiles, in which numbers increase from low to high: 39 (25.2); 46 (29.7); and 70 (45.1).

The trend seen for reptiles also applies to the herpetofauna as a whole. Of the 208 total species, 56 (26.9%) are assigned to the low category, 69 (33.2%) to the medium category, and 83 (39.9%) to the high category.

In summary, application of the EVS measure to the members of the herpetofauna of Michoacán demonstrates starkly that the absolute and relative numbers increase dramatically from the low category of scores through the medium category to the high category.

4. Comparing the results of the three systems

When we compared the results of the three conservation assessment systems, it was obvious that the EVS is the only one for which the entire land herpetofauna of Michoacán can be assessed. The EVS also is the only system that provides a fair accounting of the distributional status of species (state-level endemic, country-level endemic, and non-endemic). Furthermore, this system is cost-effective, as the authors of this paper and those of the two on the Mexican herpetofauna in this special Mexico issue assembled these contributions from their homes, simply by using the communicative ability of the Internet. The only disadvantage of the EVS is that it does not apply to marine species; today, however, a sizable number of conservation champions at least are working with marine turtles. Thus, as noted by Wilson

et al. (2013b), “given the geometric pace at which environmental threats worsen, since they are commensurate with the rate of human population growth, it is important to have a conservation assessment measure that can be applied simply, quickly, and economically to the species under consideration.” The EVS is the only one of the three systems we examined with this capacity.

Conclusions and Recommendations

1. Conclusions

A broad array of habitat types are found in Michoacán, ranging from those at relatively lower elevations along the Pacific coastal plain and in the Balsas-Tepalcatepec Depression to those at higher elevations in the Sierra Madre del Sur, the Transverse Volcanic Axis, and the Central Plateau. In total, 215 species of amphibians and reptiles are recorded from the state, including 212 native and three non-native species (*Lithobates catesbeianus*, *Hemidactylus frenatus*, and *Ramphotyphlops braminus*). The native amphibians comprise 43 anurans, nine salamanders, and one caecilian. The native reptiles constitute 151 squamates (including the marine *Pelamis platura*), seven turtles (including the marine *Chelonia mydas*, *Dermochelys coriacea*, and *Lepidochelys olivacea*), and one crocodylian.

With respect to the number of physiographic provinces inhabited, the numbers drop consistently from the lowest to the highest occupancy figures (i.e., one through five). The number of taxa in each of the provinces, in decreasing order, is as follows: Sierra Madre del Sur (103 species); Balsas-Tepalcatepec Depression (98); Transverse Volcanic Axis (97); Coastal Plain (71); and Central Plateau (29). Among the five provinces, the representation of the major herpetofaunal groups is as follows: anurans = Balsas-Tepalcatepec Depression; salamanders = Transverse Volcanic Axis (all species limited here); caecilians = Sierra Madre del Sur and Transverse Volcanic Axis (single species limited to these two provinces); lizards = Sierra Madre del Sur; snakes = Sierra Madre del Sur; turtles = Coastal Plain; and crocodylians = Coastal Plain (single species limited here). The degree of herpetofaunal resemblance is greatest between the Balsas-Te-

palcatepec Depression and the Sierra Madre del Sur. The greatest resemblance of the Coastal Plain herpetofauna also is to that of the Balsas-Tepalcatepec Depression. Finally, the greatest resemblance of the herpetofauna of the Transverse Volcanic Axis is to that of the Central Plateau, and vice versa. Within Michoacán, close to one-half of the native herpetofauna is limited in distribution to a single physiographic province, in the following decreasing order: Transverse Volcanic Axis, Coastal Plain, Balsas-Tepalcatepec Depression, Sierra Madre del Sur, and Central Plateau. Most of these single-province species also are country-level endemics.

We employed three systems for assessing the conservation status of members of the Michoacán herpetofauna (SEMARNAT, IUCN, and EVS). The SEMARNAT system was developed for use in Mexico by the Secretaría de Medio Ambiente y Recursos Naturales. Although widely used in Mexico, when this system is applied to the herpetofauna of Michoacán it leaves almost one-half of the species unassessed (i.e., having “no status”). Nevertheless, we documented and analyzed the results applying this system to the herpetofauna of Michoacán. Given the significantly incomplete coverage of the SEMARNAT system, we found it insufficiently useful for our purposes.

The IUCN system is applied and used globally. Its categories are broadly recognized (e.g., Critically Endangered, Endangered, and Vulnerable, the three so-called threat categories). Although this system presently

has been applied to a greater proportion of the herpetofauna of Michoacán (compared to the SEMARNAT system), it has not been applied to about 13% of the species. Furthermore, we question the applicability of some aspects of this system, especially with regard to the significant use of the Data Deficient category and the overuse of the Least Concern category. In addition, the expense of creating IUCN threat assessments and the manner in which they are created (e.g., workshops that bring together workers from far-flung areas of the world to a single location within the area of evaluation for several days) often is cost-prohibitive. We also found this system deficient in presenting a useful appraisal of the conservation status of Michoacán’s herpetofauna.

The EVS system originally was developed for use with amphibians and reptiles in Honduras, but later was expanded for use elsewhere in Central America. In this Special Mexico Issue of *Amphibian & Reptile Conservation*, it was applied to all of the native amphibians and non-marine reptiles of Mexico (Wilson et al. 2013a,b). We adopted the scores developed in these two papers for use with the Michoacán herpetofauna, and analyzed the results. We discovered that once all of the species were evaluated using the EVS system and allocated to low, medium, and high score categories, the number of species increases strikingly from the low through the medium to the high category.

2. Recommendations

Based on our conclusions, a number of recommendations follow:

1. Given that the degree of herpetofaunal endemism in Michoacán is greater than that for the country of Mexico, and that a substantial number of those endemic species are known only from the state, the level of protection afforded to the state’s herpetofauna is of major conservation interest. One hundred and twenty-one species are endemic at the country level and an additional 20 are endemic at the state level. Thus, the total for these two groups is 141 (66.5% of the total native herpetofauna), a figure 6.5% higher than that for the country (Wilson et al. 2013a,b). The species with the most conservation significance are the 20 state endemics, and we recommend a conservation assessment



Porthidium hespere. The western hog-nosed viper inhabits the coastal plain of western Mexico, from southeastern Colima to central Michoacán. Its EVS has been reported as 18, placing it in the upper portion of the high vulnerability category, it has been judged as Data Deficient by IUCN, and assigned a Special Protection status by SEMARNAT. This individual is from Coahuayana on the coast of Michoacán. Photo by Oscar Medina-Aguilar.

of the state's herpetofauna that focuses on the state- and country-level endemic species.

2. Michoacán contains a sizable number of protected areas at the global, national, state, and local levels. Because the distribution of the herpetofauna in these areas only is being determined, we recommend that this work be accelerated to form a database for creating a state-level conservation plan.
3. An evaluation of the level of protection afforded to the state's herpetofauna in protected areas is critical for determining areas with high species richness, a high number of endemic species, or species at risk, as well as the degree of overlap within the various protected areas.
4. We recommend an evaluation of all the protected areas in the state, based on their ability to support viable populations of the resident herpetofauna.
5. Once a distributional database is assembled for the state's herpetofauna in protected areas, and a capacity analysis completed, a robust conservation plan needs to be developed and implemented.
6. Considering that agriculture, logging, and cattle ranching are the leading factors in the local extirpation and extinction of ecosystems and their resident species, and that human-modified environments now are the dominant landscapes in the state, the potential for the conservation of the herpetofauna in these environments needs to be evaluated. Management strategies that allow for the maximal numbers of herpetofaunal species to survive and thrive in these altered landscapes also need to be defined.
7. Ultimately, humans protect only what they appreciate, and thus a conservation management plan must encompass environmental education programs for all groups of people, especially the young, as well as the involvement of local people in implementing these programs.

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Addendum

After this paper was placed in proof, we discovered a report of a new Michoacán record for *Coniophanes melanocephalus* (Carbajal-Márquez RA, Quintero-Díaz GE, and Domínguez-De La Riva MA. 2011. Geographic distribution. *Coniophanes melanocephalus* [Black-headed Stripeless Snake] *Herpetological Review* 42: 242). The specimen was found in “subtropical dry forest” at Hoyo del Aire, Municipality of Taretan, at an elevation of 887 m. This locality lies within the northernmost finger of the Balsas-Tepalcatepec Depression in central Michoacán. The EVS of *Coniophanes melanocephalus* has been assessed as 14, placing it in the high vulnerability category, its IUCN status reported as DD (Wilson et al. 2013), and no status is available in the SEMARNAT system (www.semarnat.gob.mx).

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Larry David Wilson is a herpetologist with lengthy experience in Mesoamerica, totaling six collective years (combined over the past 47). Larry is the senior editor of the recently published *Conservation of Mesoamerican Amphibians and Reptiles* and a co-author of seven of its chapters. He retired after 35 years of service as Professor of Biology at Miami-Dade College in Miami, Florida. Larry is the author or co-author of more than 290 peer-reviewed papers and books primarily on herpetology, including the 2004 *Amphibian & Reptile Conservation* paper entitled “The conservation status of the herpetofauna of Honduras.” His other books include *The Snakes of Honduras*, *Middle American Herpetology*, *The Amphibians of Honduras*, *Amphibians & Reptiles of the Bay Islands and Cayos Cochinos, Honduras*, *The Amphibians and Reptiles of the Honduran Mosquitia*, and *Guide to the Amphibians & Reptiles of Cusuco National Park, Honduras*. He also served as the Snake Section Editor for the *Catalogue of American Amphibians and Reptiles* for 33 years. Over his career, Larry has authored or co-authored the description of 69 currently recognized herpetofaunal species and six species have been named in his honor, including the anuran *Craugastor lauraster* and the snakes *Cerrophidion wilsoni*, *Myriopholis wilsoni*, and *Oxybelis wilsoni*.



Oscar Medina-Aguilar graduated from the Facultad de Biología of the Universidad Michoacana de San Nicolás de Hidalgo in 2011. He studied the herpetofauna of Tacámbaro, Michoacán, as part of his degree requirements. His interests include the systematics and distribution of the amphibians and reptiles of México. In 2011, the results of his study of the herpetofauna of Tacámbaro were published in the *Revista Mexicana de Biodiversidad*.

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